

ON PROVIDING UNIFORM EDGE
COMPRESSIVE LOADS FOR
WIDE FLAT PLATES

Milan Louis Pittman, Jr.

and

Virgil Willard Rinehart



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ON PROVIDING UNIFORM EDGE COLLECTIVE
LOADS FOR WIDE FLAT PLATES

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ON PROVIDING UNIFORM EDGE COMPRESSIVE LOADS
FOR WIDE FLAT PLATES

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SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE

DEGREE OF NAVAL ENGINEER

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

May 1954

ABSTRACT

ON PROVIDING UNIFORM EDGE COMPRESSIVE LOADS FOR WIDE FLAT PLATES

by

Milan L. Pittman and Virgil W. Rinehart

Submitted to the Department of Naval Architecture and Marine Engineering on May 24, 1954 in partial fulfillment of the requirements for the degree of Naval Engineer.

This investigation constitutes a part of a program being carried out in the Department of Naval Architecture and Marine Engineering under the auspices of the Society of Naval Architects and Marine Engineers.

Many merchant vessels are built using a transverse system of framing. These transverse frames, and the more widely spaced longitudinal stiffeners divide the ship's plating into short wide rectangular panels, which are placed either in tension or compression across the short dimension as the ship "hogs" or "sags" under the effects of loading and wave motion. In general the compressive loading is more critical due to the phenomenon of "buckling".

For test purposes these panels can be represented by wide flat plates restrained to varying degrees at their edges and loaded in compression across the short dimension. In this investigation an apparatus was designed for the determination of the buckling and ultimate loads of such plates when all four edges were simply supported (no rotational restraint). This apparatus is intended to accommodate sixteen groups of plates having all possible combinations of the following length-width ratios (a/b) and length-thickness ratios (a/t): $a/b = 1/4, 1/3, 1/2, \text{ and } 3/4$; $a/t = 30, 50, 70, 90$. Only one of these

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APPENDIX

ON THE THEORY OF THE
OF THE

BY

WILLIAM L. FLETCHER and JAMES A. HARRIS

Submitted to the Department of Naval Architecture and Marine Engineering
on May 26, 1931 in partial fulfillment of the requirements for the
degree of Naval Engineer.

This investigation constitutes a part of a program of research

carried out in the Department of Naval Architecture and Marine Engineering

under the supervision of the Faculty of Naval Architecture and Marine

Engineering.

Many important vessels are built with a transverse section of

trapezoidal form. These transverse forms, and the way in which they are

trapezoidal, differ from the usual form of the transverse section

in that, while the latter is based upon a constant or nearly constant

the short dimension as the ship "ages" or "grows" under the influence of

loading and wave motion. In general, the transverse section is more

critical due to the presence of "hogging".

For test purposes these plates are constructed of steel or

plates reinforced to varying degrees at their ends or corners.

compression across the short dimension. A transverse section

apparatus was designed for the determination of the critical load of plates

under loads of both plates and of the transverse section.

(no rotational resistance). This apparatus is described in detail in

sixteen groups of plates having all round and corner reinforcement.

Following load-shortening ratios (L/S) and load-shortening ratios (L/S)

$L/S = 1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9, 1/10, 1/11, 1/12, 1/13, 1/14, 1/15, 1/16, 1/17, 1/18, 1/19, 1/20$

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groups was actually tested, the remainder being left for future completion of the program.

From the work carried out the following conclusions are drawn:

(1) While further work is necessary to make the apparatus completely satisfactory, the equipment designed and built provided reasonably uniform distribution of the compressive load, and a very close approximation of simple support on all four edges of a test plate $56 \frac{3}{4}$ " in width, $13 \frac{5}{16}$ " in length, and $\frac{5}{32}$ " in thickness.

(2) A group of four plates was tested in buckling to augment the evaluation of the test apparatus. From these tests the following tentative conclusions are drawn:

(a) The uniformity of stress distribution is not as critical as was anticipated.

(b) The strength of the plate is not a function of the measured maximum initial unfairness alone, the initial contour and the past history being important also.

(c) For the four plates tested ($a/b = 0.237$; $a/t = 86.4$) the experimental critical stresses obtained supported the prediction for the given ratios according to Bleich [8].

groups was actually tested, the remaining being left for future
completion of the program.

From the work carried out the following conclusions are drawn:

(1) While further work is necessary to make the apparatus more

precisely satisfactory, the equipment designed and built provides

reasonably uniform distribution of the compressive load, and a very

close approximation of single support on all four edges of a plate

plates 20×10 in width, 12×10 in length, and $5/32$ in thickness.

(2) A group of four plates was tested in bending to represent

the evaluation of the test apparatus. From these tests the following

conclusive conclusions are drawn:

(a) The uniformity of stress distribution is not as critical

as was anticipated.

(b) The strength of the plate is not a function of the

measured maximum initial uniform stress alone; the initial contour and the

test history being important also.

(c) For the four plates tested ($\sigma_0 = 0.817$; $\sigma_0 = 0.817$) the

experimental critical stresses obtained supported the prediction for

the given ratios according to Equation (8).

Cambridge, Massachusetts
May 24, 1954

Professor Leicester F. Hamilton
Secretary of the Faculty
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

Dear Sir:

In accordance with the requirements of the degree of Naval Engineer, we herewith submit a thesis entitled "On Providing Uniform Edge Compressive Loads for Wide Flat Plates".

ACKNOWLEDGMENT

The authors wish to express their deep appreciation of the patient and helpful guidance of Professor C. H. Morris throughout the whole period of this endeavor.

$$x = \frac{1}{2} \left(\frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}} \right)$$

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$$x = \frac{1}{2} \left(\frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}} \right)$$

ON PROVIDING UNIFORM EDGE COMPRESSIVE
LOADS FOR WIDE FLAT PLATES

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NOTATION

a	- Unsupported length between centers of loading segments
b	- Unsupported length between "a"-edge supports
b'	- Actual width of plate
d	- Lateral deflection of center of plate from original plane
d ₀	- Initial lateral deflection of center of plate (zero load)
d'	- Distance from point on horizontal center line of plate to reference line
k	- Coefficient in buckling formula (based on b/t)
K	- " " " " (based on a/t)
n	- Number of half waves in buckled plate
t	- Thickness of plate
w	- Lateral deflection of an arbitrary point on the neutral plane of the plate from the original plane
x	- Distance in direction of load (origin at horizontal cl.)
y	- " normal to " (origin at one edge)
A	- Edge area of plate - b't
C	- Arbitrary constant in solution of differential equation
D	- Plate constant - $AI/(1-\nu^2)$
E	- Young's modulus of elasticity
E _t	- Tangent modulus
F	- Friction force in one jack
I	- Moment of inertia of strip of plating 1" wide, t thick - $t^3/12$
L	- Same as "a" - used in column formulae
P	- Applied load
P'	- Load transmitted to test plate
P _{cr}	- Critical load

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P_{ult}	- Ultimate load
P_i	- Internal pressure in jack manifold
S	- Force exerted by jack plunger return spring
α	- a/b - aspect ratio or width ratio
$\epsilon_{1,2}$	- Measured strains for pair of opposite gages
ϵ_z	- Longitudinal strain at neutral axis of plate
ϵ_{av}	- Average longitudinal strain - P/AE
f	- Coefficient of edge restraint ($f=\infty$ for simple support)
μ	- Micro- (one-millionth)
ν	- Poisson's ratio - assumed to be 0.3
σ	- Stress intensity
σ_z	- Longitudinal stress intensity at neutral axis
σ_{av}	- Average longitudinal stress intensity - P/A
σ_{cr}	- Critical stress intensity
σ_{ult}	- Ultimate stress intensity
σ_y	- Yield stress
τ	- E_t/E

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I. INTRODUCTION

A. General

This investigation represents a part of a more extensive program being sponsored by the Hull Structures Committee of the Society of Naval Architects and Marine Engineers. (See Appendix A.) This project is designed to determine the buckling and ultimate strengths of flat plates of such dimensions and boundary conditions as those usually found in transversely framed merchant vessels.

The framing of a vessel may be considered, for the purposes of such an investigation, as the boundaries of the various panels into which it divides the ship's skin or plating. Each of these panels may be acted upon by direct axial loads, shear forces, and/or moments along either or both edges, and in addition by pressure forces normal to the plane of the plate. Due to the behavior of the plating as a whole, the edges of a particular panel may be considered as simply supported, elastically restrained, or in the extreme condition, clamped. Variables which affect the plating strength are: (1) the ratio of plating length to thickness; (2) the ratio of length to width; (3) the degree of restraint against rotation of the plate edges; (4) the stiffness of panel boundaries, (5) effect of non-uniform distribution of the load.

B. Research Project

It was felt by the Hull Structures Committee that the experimental data on the strength of these "wide" plates was incomplete and that a considerable range of plating sizes and shapes utilized in ship construction had not been investigated at all. As a specific point, Montgomery's

A. General

This investigation represents a part of a more extensive program

being sponsored by the Ball Structures Committee of the Society of

Naval Architects and Marine Engineers. (See Appendix A.) This project

is designed to determine the buckling and ultimate strengths of flat

plates of such dimensions and boundary conditions as those usually found

in transversely framed warship vessels.

The framing of a vessel may be considered, for the purpose of such

an investigation, as the presence of the various panels into which it

divides the ship's side or plating. Each of these panels may be acted

upon by direct axial loads, shear forces, and/or moments along either or

both edges, and in addition by pressure forces normal to the plane of the

plate. Due to the behavior of the plating as a whole, the edges of a

particular panel may be considered as simply supported, clamped,

free, or in the extreme condition, skewed. Factors which affect

the plating strength are: (1) the ratio of plating length to width;

(2) the ratio of length to width; (3) the degree of restraint against

rotation of the plate edges; (4) the thickness of panel members; (5)

effect of non-uniform distribution of the load.

B. Research Project

It was felt by the Ball Structures Committee that the experimental

data on the strength of these "flat" plates was inadequate and that a

considerable range of plating stress and strain should be investigated

that had not been investigated previously. As a specific project, the

results [36], based upon tests on plates with unloaded edges free and loaded edges elastically restrained have been applied to conditions where they are not valid, in lieu of better data. Accordingly a research project was formulated which had as its aim the accomplishment of the following four purposes:

- Phase I To make a survey of the literature relating to the theoretical buckling and ultimate strengths and experimental work thereon; to determine the ranges of parameters for which experimental data was lacking or insufficient; and to find information upon the effect and growth of unfairness.
- Phase II To conduct buckling and ultimate strength tests for uniaxial edge compression on plates of such dimensions as are indicated by Phase I, with loaded and unloaded edges simply supported.
- Phase III To conduct buckling and ultimate strength tests for uniaxial edge compression on plates of such dimensions as are indicated by Phase I, with unloaded edges simply supported and loaded edges elastically restrained to varying degrees.
- Phase IV To design, build, and evaluate a test apparatus for the accomplishment of Phases II and III.

It was the original purpose of the authors to complete Phases I, II, and IV. However, due to delays in delivery of the test equipment, and to difficulties encountered in getting the test equipment to function as desired, Phase IV was not completed to the entire satisfaction of the authors. One group of plates under Phase II was tested but its results

results [35], based upon tests on 40000 with rounded edges from and
loaded edges elastically restrained have been applied in combination
there they are not valid in line of better data. Accordingly
research project was formulated which had as its aim the investigation

of the following four questions:

Phase I To make a survey of the literature relating to the
theoretical bending and ultimate strength and
experimental work thereof; to determine the range of
parameters for which experimental data was lacking or
insufficient; and to find information upon the effect
and growth of imperfections.

Phase II To conduct bending and ultimate strength tests for
circular edge compression on plates of two dimensions
as was indicated by Phase I, with loaded and unloaded
edges elastically supported.

Phase III To conduct bending and ultimate strength tests for uni-
circular edge compression on plates of two dimensions as
was indicated by Phase I, with unloaded edges elastically
supported and loaded edges elastically restrained to
varying degrees.

Phase IV To design, build, and conduct a test program for the
accomplishment of Phases II and III.

It was the original purpose of the author to complete Phases I, II,
and IV. However, due to delays in delivery of the test equipment, and to
difficulties encountered in setting the test equipment in location as
desired, Phase IV was not completed to the extent anticipated of the
author. The group of plates under Phase II was tested but the results

are intended primarily to supplement the evaluation of the test equipment under Phase IV.

5. Literature Survey

A search of the literature on, or pertaining to, buckling ultimate strength of flat plates under various loadings and edge conditions was made to determine whether adequate theory and experimental data existed pertinent to the range of plate parameters and edge conditions under investigation.

The results of this search led to the belief that theory presented by F. B.leich [8] was an adequate, though not mathematically precise, basis for judging the proposed test results, both for buckling and ultimate strength in the elastic and plastic ranges.

The search failed to reveal sufficient experimental data in the region of interest. Shultz and Weechler [45] ran five tests at $a/b = 1/2$ with a/t varying from 20 to 120 with all edges simply supported. Yoshiki 59 also presents similar data skirting the range of interest, with the closest data at $a/b = 1/3$ and $1/2$ but $a/t > 100$. Figure 1A is provided to indicate the range of interest, the proposed test parameters, and the parameters for which data is presently available.

There is also some possibility that other data found may be reevaluated into usable form when considering elastic support of the loaded edges. Various shapes were used as edge restraints but no attempt was made to evaluate the degree of restraint provided.

—give him and his children all advantages of military education

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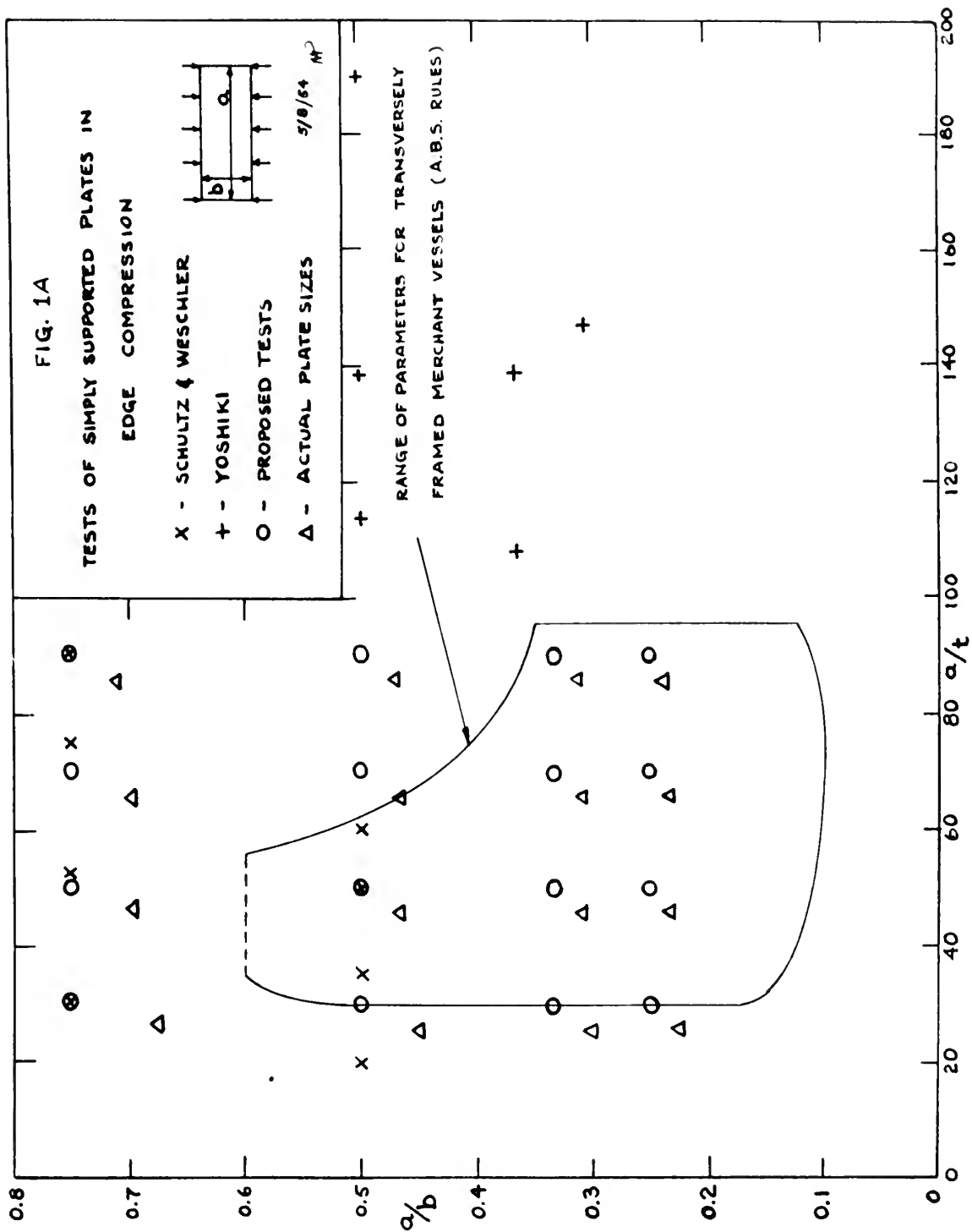
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The main result is that the function $f(x)$ is not identically zero. This is proved by showing that $f(x)$ is not identically zero on any interval of length $1/n$. The proof is by contradiction. Assume that $f(x)$ is identically zero on some interval of length $1/n$. Then, by the definition of $f(x)$, we have $f(x) = 0$ for all x in this interval. This implies that $f(x)$ is identically zero on the entire interval $[0, 1]$. This contradicts the assumption that $f(x)$ is not identically zero. Therefore, $f(x)$ is not identically zero on any interval of length $1/n$.

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D. Experimental Program

After considering the region of interest and the points covered by previous investigators it was decided to use sixteen different size test plates having combinations of the following ratios:

$$\begin{array}{rcll} a/b & - & 1/4 & , \quad 1/3 & , \quad 1/2 & , \quad 3/4 \\ a/t & - & 30 & , \quad 50 & , \quad 70 & , \quad 90 \end{array}$$

These particular values were chosen for the following reasons:

1. Within the region of interest there has been very little data obtained, and the theory has not been confirmed.
2. Some of the a/b values lie above the region outlined by the American Bureau of Shipping Regulation, since the ABS values are for plates near the midship section, and the plates farther forward or aft have higher a/b ratios.
3. For extremely low a/b ratios, repeatable results are difficult to obtain, and it was decided to concentrate on getting usable results for the intermediate values.
4. Higher a/b ratios are of interest primarily for longitudinally framed ships.

Actual sizes for the test specimens were decided upon after consideration of the following factors:

1. The a/b , a/t ratios decided upon above.
2. In order to use existing equipment previously used in investigations by Polychrone [40] and Capozzoli [12], the sum of one of each short dimension chosen was not to exceed $34''$.
3. The long dimensions were calculated from the short dimensions and the a/b ratios selected above.
4. The maximum plate thickness which could be accommodated by the

D. Experimental Program

After considering the region of interest and the points covered by previous investigators it was decided to use sixteen different plate

test plates having combinations of the following ratios:

a/b	-	$1/2$	$1/3$	$1/4$	$1/5$	$1/6$	$1/8$
a/c	-	30	50	70	90	110	130

These particular values were chosen for the following reasons:

1. Within the region of interest there are very little data obtained, and the theory has not been confirmed.
2. Some of the a/b values lie above the region outlined by the American Bureau of Shipping Regulations, since the a/b values are for plates near the midship section, and the plates farther forward or aft have higher a/b ratios.
3. For extremely low a/b ratios, reasonable results are difficult to obtain, and it was decided to concentrate on getting usable results for the intermediate values.
4. Higher a/b ratios are of interest primarily for longitudinal stresses.

Actual plates for the test specimens were machined from steel and

illustration of the following features:

1. The a/b , a/c ratios desired were chosen.
2. In order to get existing equipment, provisionally used in investigation by Polymers [10] and [11], the use of an a/b ratio of 1/2 was chosen since this was not so unusual.
3. The long dimension was determined from the a/b ratio chosen and the a/c ratio selected above.
4. The various plate thicknesses which would be accommodated by the

"a-edge" supports was $5/16$ ". In addition it was desirable to use standard plate thicknesses.

5. Since it was desired to obtain both buckling and ultimate strengths, the plates should fail under a load less than the capacity of the testing machine (300,000 pounds).

6. The "a" and "b" dimensions, as determined above were then altered as follows:

(a) The "a" dimension was decreased by $3/4$ " since it was believed at this time that the loading segments which transmitted the load would act as a part of the effective length of plate. (It was later decided that this was not the case, and hence the actual a/b and a/t values were not exactly the same as had been selected.) The actual plate dimensions are given in Table I.

(b) The "b" dimension was increased by $1/2$ " to allow $1/4$ " extension beyond the line of ball bearing support at each unloaded edge.

"a-10" reports are 2/15. In addition it was decided to use

standard price information.

2. Since it was decided to obtain price information on a regular

basis, the plan should be to have a list of items to be priced

of the pricing committee (200,000 items).

3. The "a-10" information is to be used in the "a-10" report

as follows:

(a) The "a-10" information was determined by 1/15. Since it was

decided to use this information in the pricing committee report

which the plan should be to have a list of items to be priced

of items. (It was later decided that this was not the case)

and hence the information of 1/15 was not used in the pricing

committee report. The information was used in the "a-10" report

as follows:

(b) The "a-10" information was determined by 1/15. Since it was

decided to use this information in the pricing committee report

as follows:

TABLE I
Plating Dimensions

Nominal		Nominal a/t			
a/b		30	50	70	90
3/4	l	6.750	10.188	10.188	13.313
	w	10.500	15.080	15.080	19.25
	t	1/4	7/32	5/32	5/32
	a/b	.675	.699	.699	.710
	a/t	27.0	46.5	65.2	85.2
1/2	l	6.750	10.188	10.188	13.313
	w	15.500	22.375	22.375	28.625
	t	1/4	7/32	5/32	5/32
	a/b	.450	.465	.465	.474
	a/t	27.0	46.5	65.2	85.2
1/3	l	6.750	10.188	10.188	13.313
	w	23.000	33.513	33.513	42.688
	t	1/4	7/32	5/32	5/32
	a/b	.300	.310	.310	.316
	a/t	27.0	46.5	65.2	85.2
1/4	l	6.750	10.188	10.188	13.313
	w	30.500	44.25	44.25	56.75
	t	1/4	7/32	5/32	5/32
	a/b	.225	.233	.233	.237
	a/t	27.0	46.5	65.2	85.2

TABLE 1

Continued from page 1

Station				Depth	
No.				Feet	
10	10	10	10	10	10
10.01	10.01	10.01	10.01	10	10
10.02	10.02	10.02	10.02	10	10
10.03	10.03	10.03	10.03	10	10
10.04	10.04	10.04	10.04	10	10
10.05	10.05	10.05	10.05	10	10
10.06	10.06	10.06	10.06	10	10
10.07	10.07	10.07	10.07	10	10
10.08	10.08	10.08	10.08	10	10
10.09	10.09	10.09	10.09	10	10
10.10	10.10	10.10	10.10	10	10
10.11	10.11	10.11	10.11	10	10
10.12	10.12	10.12	10.12	10	10
10.13	10.13	10.13	10.13	10	10
10.14	10.14	10.14	10.14	10	10
10.15	10.15	10.15	10.15	10	10
10.16	10.16	10.16	10.16	10	10
10.17	10.17	10.17	10.17	10	10
10.18	10.18	10.18	10.18	10	10
10.19	10.19	10.19	10.19	10	10
10.20	10.20	10.20	10.20	10	10
10.21	10.21	10.21	10.21	10	10
10.22	10.22	10.22	10.22	10	10
10.23	10.23	10.23	10.23	10	10
10.24	10.24	10.24	10.24	10	10
10.25	10.25	10.25	10.25	10	10
10.26	10.26	10.26	10.26	10	10
10.27	10.27	10.27	10.27	10	10
10.28	10.28	10.28	10.28	10	10
10.29	10.29	10.29	10.29	10	10
10.30	10.30	10.30	10.30	10	10
10.31	10.31	10.31	10.31	10	10
10.32	10.32	10.32	10.32	10	10
10.33	10.33	10.33	10.33	10	10
10.34	10.34	10.34	10.34	10	10
10.35	10.35	10.35	10.35	10	10
10.36	10.36	10.36	10.36	10	10
10.37	10.37	10.37	10.37	10	10
10.38	10.38	10.38	10.38	10	10
10.39	10.39	10.39	10.39	10	10
10.40	10.40	10.40	10.40	10	10
10.41	10.41	10.41	10.41	10	10
10.42	10.42	10.42	10.42	10	10
10.43	10.43	10.43	10.43	10	10
10.44	10.44	10.44	10.44	10	10
10.45	10.45	10.45	10.45	10	10
10.46	10.46	10.46	10.46	10	10
10.47	10.47	10.47	10.47	10	10
10.48	10.48	10.48	10.48	10	10
10.49	10.49	10.49	10.49	10	10
10.50	10.50	10.50	10.50	10	10

II. PROCEDURE

A. General

The analysis of the behavior of flat plates is based upon a given stress distribution, in this case the distribution of the force applied at the loaded edges. The problem, then, was to provide a means of applying a uniformly distributed edge load and at the same time to maintain simple support at the loaded edges, so that the edges of the plate were allowed complete freedom of rotation and freedom of translation in the plane of the plate while being restricted from any lateral movement.

B. Load Distribution

A uniform load distribution can be obtained by one of two methods, either by causing a uniform contraction in the plane of the plate, or by applying a load which is distributed by some external system. Either of these methods provides the desired loading condition prior to buckling of a perfectly flat plate. In the case of a plate in a ship's structure, the assumption that the "loaded" edges of a panel remain straight (uniform deflection loading) is probably closer to the actual situation than is the assumption of a uniform load distribution. However for reasons given below, this method of loading is very difficult to use.

The available testing machine, shown in Fig. 34, has an upper loading head which is a hollow cylindrical forging approximately 18" outside diameter, and 11" inside; the lower head is 24" square. Since the largest plate is 56 3/4" wide, some auxiliary device was necessary to distribute the load to the plate. Preliminary calculations indicated that an I-beam

A. General

The analysis of the behavior of the system is based on a given stress distribution. In this case the distribution of the force applied at the loaded edges. The position, then, can be treated as a case of applying a uniformly distributed edge load and at the same time to obtain a single support at the loaded edges, so that the edges of the plate were allowed complete freedom of rotation and freedom of transverse movement. The plane of the plate being considered from any internal movement.

B. Load Distribution

A uniform load distribution can be obtained by one of two methods, either by causing a uniform contraction in the plane of the plate, or by applying a load which is distributed by some external system. In the first method, whether the desired loading condition is to be obtained of a perfectly flat plate. In the case of a plate in a single system, the assumption that the "loaded" edges of a panel remain straight and uniform deflection loading) is probably closer to the actual situation than is the assumption of a uniform load distribution. However, the former gives better, this method of loading is very different from the latter. The available loading machine, shown in Fig. 1, has two rigid loading heads which is a hollow cylindrical loading apparatus 12" diameter, 12" thick, and 12" thick; the lower head is 12" diameter, 12" thick, and 12" thick, some specially chosen material is used in the form of the plate. The loading condition is shown in Fig. 2.

which would limit the diminution of the stress near the ends of the plate to a nominal value, say 5% of the average, would be of prohibitive size. This analysis is borne out by the fact that the constant deflection heads of the testing machine at the David Taylor Model Basin are extremely deep.

The solution commensurate with the time and money available was the use of a system of seven 20-ton Blackhawk Porto-Power hydraulic jacks connected to a common manifold, identical systems being used at both the top and bottom of the plate. The testing machine transmitted the load through an 18-inch wide flange I-beam to the jacks which in turn applied the load to the plate through the arrangement intended to provide simple support. This system, while not exactly reproducing the practical situation, provided a solution which was feasible, and gave known conditions of loading.

Bridging the gaps between the jacks was a $3/4"$ x $3-5/8"$ x 5' bar of AISI C-1045 steel hardened to 50 Rockwell C. The purpose of this bar was to further distribute the load between the jacks when they were widely separated, and served as a bearing surface against which the loading segments bore. The bar was ground flat on one side, and on the other had a shallow groove ground to allow two alternative ways of using the bar.

The loading segments transmitted the load from the loading bar to the plate itself. These segments were cut from $3/4"$ diameter drill rod which had a longitudinal groove milled to center depth; the rod was then cut to lengths of $7/8"$ and $1/2"$, the shorter segments being placed at the end of the plate. These segments were hardened to a hardness comparable to that of the loading bar. These segments transmitted the load along a radius to the edge of the plate. In this way torsional restraint along

which would limit the thickness of the plates near the ends of the plate to a nominal value, say $\frac{1}{16}$ of an inch, would be of considerable value. This analysis is borne out by the fact that the constant deflection limits of the testing machine at the fixed points tested herein were extremely large.

The solution commences with the data now being available and the use of a system of seven 10-ton hydraulic rams, which are connected to a common manifold, identical systems being used at both the top and bottom of the plate. The testing machine transmitted the load through an 18-inch wide I-beam to the jaws which in turn applied the load to the plate through the arrangement intended to provide rigid support. This system, while not exactly reproducing the practical situation, provided a solution which was feasible, and gave some indication of loading.

Regarding the gaps between the jaws was $\frac{1}{16}$ in. \times $\frac{1}{16}$ in. \times $\frac{1}{16}$ in. of A131 6-10K2 steel hardened to 50 Rockwell C. The purpose of this was to further distribute the load between the jaws from their own weight separated, and served as a bearing surface against which the loading was borne. The bar was ground flat on one side, and on the other had a shallow groove ground to allow the alternative ways of using the bar. The loading segments transmitted the load from the loading bar to the plate itself. These segments were cut from 1 1/2" diameter drill rod which had a longitudinal groove milled to center depth; the rod was cut out to lengths of 7/8" and 1 1/2", the shorter segments being placed at the end of the plate. These segments were hardened to a hardness comparable to that of the loading bar. These segments transmitted the load along a radius to the edge of the plate. In this way stresses were relieved along

the plate edge was negligible, the plate edge was free to rotate, and the sliding friction and/or the groove in the loading bar prevented lateral movement of the plate edges. It is believed that a very close approximation to simple support was achieved.

In the design of the segments, sufficient clearance was allowed in the milled slot so as to reduce the probability of a notch failure at the internal corners. To reduce the amount of eccentricity of loading, shimming strips 0.017 inches thick were inserted between the plate sides and the segments. (See Figure 27.)

After the first test showed that the load distribution was quite erratic, a gasket of neoprene was inserted between the plate edges and the loading segments for the purpose of eliminating local hard spots. In later tests gaskets of $3/32$ " and double $1/16$ " diameter resin core solder were used for this same purpose. Although the problem of hard spots was not completely solved by this means, it was reduced so as to indicate the use of the gaskets was beneficial.

C. Instrumentation

To obtain the required strain measurements, Type A-3 SR-4 electric strain gages were mounted on opposite sides of the plate at the center of the plate, and in some cases at additional locations along the horizontal center line. For the purpose of determining the distribution of the applied load, gages were also mounted along the top and bottom edges as close to the edge as possible to measure the least favorable distribution. (See Fig. 1B.) A four-arm Wheatstone bridge having as active gages, the gage on the plate and a compensating dummy gage on an unloaded plate of the same thickness, was used; the strains were read on a Baldwin

the plate edge was negligible, the plate was used as a reference. The sliding distance and/or the groove in the loading was measured. The lateral movement of the plate edges. It is believed that a very close approximation to single support was achieved.

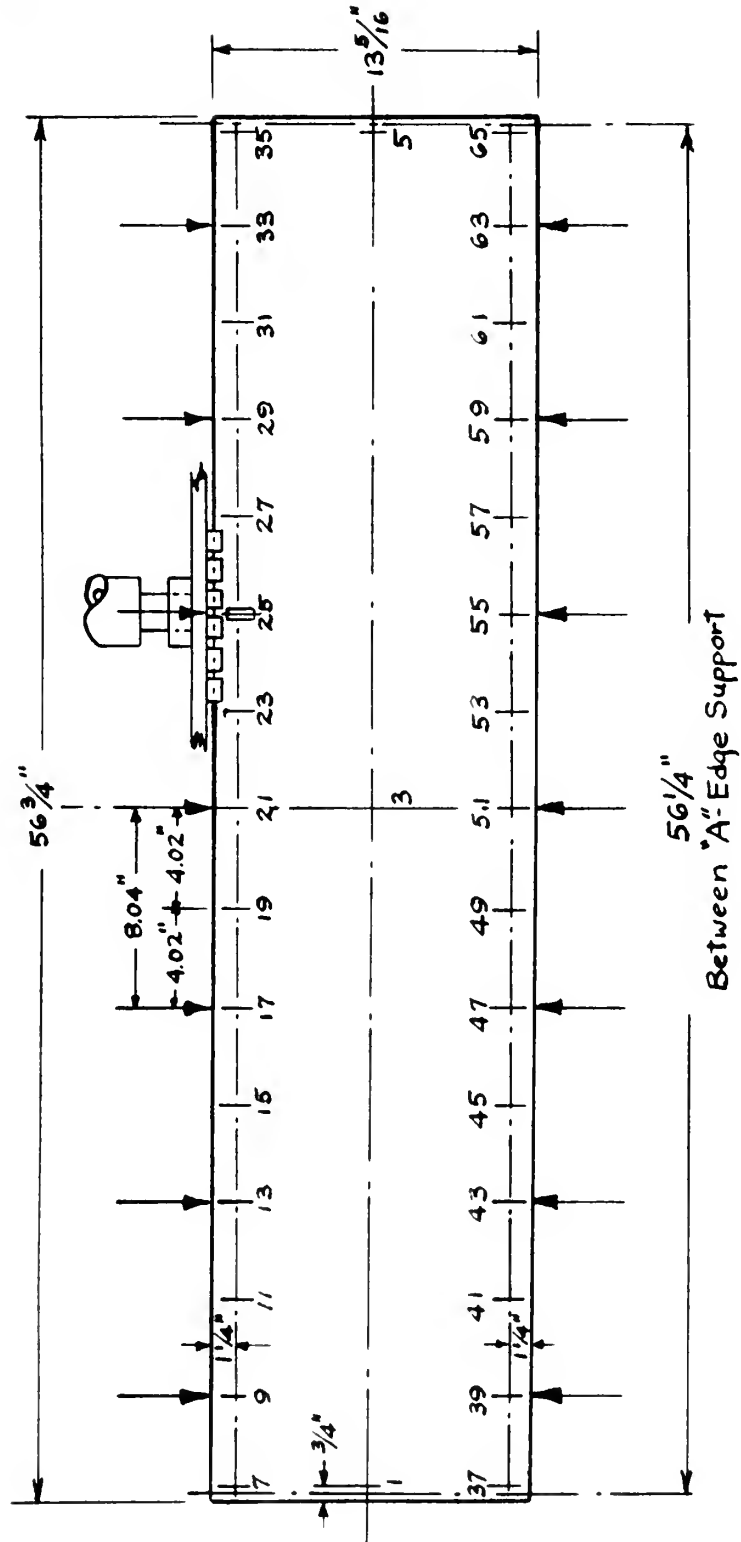
In the design of the segments, attention was given to the width of the plate as to prevent the possibility of a lateral movement of the lateral segments. In order to prevent the possibility of lateral movement, the following design was used: (See Figure 1.)

After the first test showed that the load distribution was quite erratic, a number of segments was inserted between the plate edges and the loading segments for the purpose of eliminating lateral movement. In later tests segments of 1/2" and 1/4" diameter were used. It was found that for this size segment, although the problem of lateral movement was not completely solved by this means, it was reduced to an extent that the use of the segments was satisfactory.

3. Instrumentation

To obtain the required stress measurements, Type A-3 strain gauges were used. The gauges were mounted on opposite edges of the plate at the center of the plate, and in some cases at additional locations along the length of the plate. For the purpose of determining the distribution of the applied load, gauges were also mounted along the top and bottom edges of the plate as shown in Figure 2. It was found that the load distribution was quite uniform. A four-point bending fixture was used as shown in Figure 3. The gauges on the plate and a corresponding strain gauge on the plate of the same thickness was used; the strain was measured in a similar

FIG.
TEST PLATE
No. 1



Details of Locations of Jacks & Strain Gages

Note: Even numbered gages on opposite side

Type K (or L) Strain Indicator. Strain readings could be read to ± 2 microinches/inch. Although the accepted accuracy is ± 5 microinches/inch, differences of ± 10 microinches/inch between initial and final zero readings were not uncommon, and occasional shifts of greater magnitude were recorded. However, in most cases the zero shift was from 0-8 microinches/inch.

Lateral deflections were measured by an Ames dial gage with a range of 0.500 inch, mounted so as to slide along a planed angle iron at the horizontal center line of the plate. (See Figs. 30 and 32.) The dial gage itself was accurate to within ± 0.001 inch. However, even though the angle upon which the gage was mounted was calibrated when the system was unloaded, no attempt was made to check whether or not it deformed any when the system was loaded.

The total load applied was measured on Massachusetts Institute of Technology testing machine No. 105, a hydraulic installation built by Southwark-Emery with a capacity of 300,000 pounds. On the lower scale (0-30,000 pounds) loads could be read to ± 10 pounds, and when the machine was used to apply the load, the load could be maintained to ± 50 pounds of the desired value. When the hand pump was used to apply the load, comparable accuracy could be obtained, the load readings being taken on the testing machine.

As an additional check on the total load, a Babcock and Wilcox gage with a range of 0-1000 psi was used to measure the pressure at the manifold of the upper jack system for some tests.

D. Preparation of Test Plates

The test plates were provided by Bethlehem Steel Co., Shipbuilding

Type I (or I) strain indicator. Strain readings could be read to ± 1 microstrain. Although the accepted accuracy is ± 2 microstrain, differences of ± 1.0 microstrain (load between initial and final) were not uncommon, and occasional shifts of greater magnitude were recorded. However, in most cases the same shift was from 0-5 microstrain.

Initial deflections were measured by an in-line dial gage with a range of 0.001 inch, mounted so as to slide along a ground angle iron on the horizontal center line of the plate. (See figs. 10 and 11.) The dial gage itself was accurate to within ± 0.001 inch. However, even though the angle upon which the gage was mounted was calibrated when the system was unloaded, no attempt was made to check whether or not it deflected any when the system was loaded.

The total load applied was measured on a Macintosh scale of 0-10,000 pounds with a capacity of 100,000 pounds. On the lower scale (0-10,000 pounds) loads could be read to ± 10 pounds, and when the machine was used to apply the load, the load could be maintained to ± 20 pounds of the desired value. When the hand pump was used to apply the load, comparable accuracy could be obtained, the load readings being taken on the testing machine.

As an additional check on the total load, a Sargent and Greenleaf with a range of 0-1000 psi was used to measure the pressure in the manifold of the water tank system for some tests.

D. Preparation of Test Plates

The test plates were provided by Bethlehem Steel Co., Bethlehem,

Division, Quincy, Mass. They were laid out in the same direction and cut from a single steel plate. Of the sizes of plates for which the apparatus was designed it is considered that the group of plates with the lowest aspect ratio ($1/4$), i.e., those having the longest loaded edge, presented the most difficult problem in securing a reasonably uniform load distribution. Hence this group of four plates was selected to evaluate the apparatus. The opposite edges of all test plates were planed parallel to each other.

In order to mount strain gages on the plates it was found expedient to sand-blast or shot-blast these plates in order to remove the mill scale. One of this group of plates, Plate No. 1, was selected and instrumented along both edges as shown in Fig. 1B. SR-4 type A-3 strain gages were mounted close to each loaded edge so as to fall under and in between each of the jacks. Gages were mounted in opposite pairs on both sides of the plate and connected so each gage could be read individually. Hence both bending moments and direct stress can be found. Plate No. 2 was instrumented with five pairs of gages located on the center line of the plates along the "b" dimension as shown in Fig. 23. Plates Nos. 3 & 4 each have one pair of gages located at the center of the plate.

Due to the shearing, machining, and blasting, the test plates were slightly curved in both directions. This curvature was minimized as far as practicable by subsequent rolling. It was found that the curvature remaining in the long direction could be straightened by inserting blocking between the plate and the angles connecting the "a"-edge supports. These blocks were removed before the first readings were taken. When the grooved side of the loading bar was used, this was not necessary. The curvature along the shorter dimension is treated as an initial unfairness.

During the first run on Plate No. I (Fig. 1B) the specimen was inadvertently buckled and an ultimate load of 35000 pounds was recorded. At this time it was expected that this ultimate load would be higher. Hence it was necessary to re-straighten Plate No. I before further testing could proceed. This was accomplished successfully using the testing machine as a press.

E. Evaluation of Test Apparatus

A total of eighteen tests on Plate No. I were run with the test apparatus to determine the load distribution. In each of these tests some detail of the loading system was changed, such as the jacks (with or without), loading bar, gasket, shimming, or loading segments. In all of these tests the same plate was used since a total of 60 gages were installed on it for this purpose and it was not practical to instrument more plates this fully. In each test a load of about 20,000 pounds was applied and held for several minutes to set the gasket. The load was then removed, and re-applied in progressive steps, gages being read at several values of the load.

F. Buckling Tests

Buckling tests were made on the plate used in part D above, and on three other plates of the same size. It should be pointed out that these tests were made to augment the evaluation of the machine and not primarily to obtain buckling data.

In each of the buckling tests, the load was applied by means of a hand pump connected to the manifold of the upper jack system. Zero readings of the strain gages were taken when the plates were in place

During the time that the ...

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2. Evaluation of the system

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3. Concluding Remarks

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ready for testing but before any load was applied. The load was applied in increments of 2000 pounds and strain gage readings taken. At certain loads further readings were taken for gages other than those giving buckling data in order to check the load distribution. Some lateral deflections of the plate were also recorded.

To obtain the ultimate load, the lower head of the test machine was moved up until the load began to decrease. This was taken as the ultimate load.

III. RESULTS

A. Equipment Evaluation Tests

1. General

The results of evaluation tests run on test plate No. 1 (see Fig. 1B) are presented graphically in Figures 1 to 20 inclusive. These plots depict average strain readings $1\frac{1}{4}$ " from each loaded edge of the plate under and between each hydraulic jack position along the "b" edges. Original data and sample calculations on selected tests are given in Appendices G and H respectively.

To supplement the abbreviated description of the test on each of the Figures 1 to 20 inclusive there is presented here a code of test description. A more detailed description will be found in Appendix B.

2. Code of Test Description

a. Load Application

- (1.) Machine - Load applied with 300,000 # hydraulic testing machine, No. 105, Testing Materials Laboratory.
- (2.) Pump - Load applied with hydraulic hand pump through top system of jacks.

b. Jacks

- (1.) Seven 20-ton hydraulic jacks on each edge as shown in Fig 27 and connected to a common manifold. (Fig. 30).

c. No Jacks

- (1.) All jacks removed. Loading bar bearing directly on I-beams.

A. Equipment Evaluation Tests

1. General

The results of evaluation tests run on test plate No. 1 (see Fig. 12) are presented graphically in Figure 1 to 10 inclusive. These plots depict average strain readings ϵ in μ strain units. Loaded edge of the plate under test is shown in Figure 1. Position along the "x" axis. Graphical data are shown relative to one or selected tests are given in Figures 2 and 3 respectively.

To represent the observed description of the test on each of the Figures 1 to 10 inclusive there is presented here a code of test description. A more detailed description will be found in Appendix B.

2. Code of Test Description

a. Load Application

(1) Reaction - Load applied with ϵ in μ strain

loading method, ϵ in μ strain, ϵ in μ strain

(2) Test - Load applied with ϵ in μ strain

through top surface of plate

b. Test

(1) Stress ϵ -strain relationship tests on each edge of plate

in Fig 12 and compared to a known value, ϵ in μ strain

c. No Test

(1) All tests were run, loaded and unloaded

on 1-plate.

d. Bar - Loading Bar

(1.) $3/4"$ - Designates hardened steel bar $3/4" \times 3 \ 5/8"$

See Fig. 27.

(a) (F) - Flat side of bar toward loading segments.

(b) (G) - Grooved side of bar toward loading segments.

(2.) $1/16"$ - Designates thickness of cold rolled steel bar - $1 \ 1/2"$ wide.

(3.) $1/4"$, $5/16"$, $3/8"$ - Designates thickness of cold, rolled steel bar $1 \ 1/4"$ wide.

e. Gasket - Description of gasket material between edge of test plate and loading segments

(1.) Neoprene - $1/16" \times 1/8"$ cut from neoprene sheet.

(2.) Solder - strip cut from roll of rosin core solder.

a) $3/32"$ - Diameter. Single strip per edge of plate

b) $1/16"$ - Diameter. Double strip side by side per edge of plate

f. Shims

(1.) $0.017"$ shim stock inserted between each side of segment groove and side of test plate. Remaining clearance $\approx 0.003"$

g. No Shims

(1.) Shims removed. Clearance between segment slot and plate approximately $0.035"$.

h. Load

(1.) Gage reading of 300,000 # testing machine.

4. Bar - Landing bar

(1.) $2\frac{1}{2}''$ - Designation thickness steel bar $2\frac{1}{2}'' \times 2\frac{1}{2}''$

Bar size: 21.

(a) (7) - This side of bar toward landing segment.

(b) (8) - Grooved side of bar toward landing

segment.

(2.) $1\frac{1}{2}''$ - Designation thickness of cold rolled steel

bar - $1\frac{1}{2}''$ wide.

(3.) $1\frac{1}{2}''$, $2\frac{1}{2}''$, $\frac{1}{2}''$ - Designation thickness of cold

rolled steel bar $1\frac{1}{2}''$ wide.

5. Girder - Description of girder material between ends of

two plates and landing segment.

(1.) Temperature - $1\frac{1}{2}'' \times 1\frac{1}{2}''$ and three temperature plates.

(2.) Section - Strip and three full of width three plates.

a) $1\frac{1}{2}''$ - Diameter. Strip ends are ends of plate

b) $\frac{1}{2}''$ - Diameter. Double strip ends are ends of

ends of plate

6. Straps

(1.) $0.015''$ strip about inserted between each side of

segment girder and side of foot plate. Temperature plates.

area $\approx 0.015''$

7. No Straps

(1.) Straps removed. Clearance between segment plate and

plate approximately $0.015''$.

8. Foot

(1.) Legs coming off $0.015''$ to landing segment.

1. Test Plate Orientation

(1.) Orientation indicated by showing location by number of end gages on the test plate.

j. Computed Strain

(1.) Average computed strain for a load of 10,000 lbs., 40.3 micro inches per inch, is shown as a horizontal dashed line.

B. Buckling Tests

Four plate specimens were tested to ultimate failure in the testing apparatus. Results of the tests are shown in Table II and Fig. 21.

Deflections and strain gage readings are shown in Appendix H.

The failure of each plate was observed to be one sided in both a and b directions.

In each test the load was applied with the hand pump and shims were inserted between the plate and leveling segments. Plates 1 & 2 were tested with double 1/16" diameter solder gaskets and with the flat side of the 3/4" loading bar toward the segments. Plates 3 & 4 were tested with single 3/32" diameter solder gasket with the grooved side of the 3/4" bar towards the loading segments.

1. Test Plate Orientation

(1.1) Orientation indicated by shading location of

number of and pages on test plate.

2. Test Plate Orientation

(1.2) Average computed from a total of 10,000 test

plates. The average is shown as a horizontal

line.

3. Test Plate Orientation

Test plate specimens were tested to determine failure in the testing

apparatus. Results of the tests are shown in Table III and Fig. 11.

Orientation and average values are shown in Appendix B.

The failure of each plate was observed to be due to both a

and a direction.

In each test the load was applied with the hand pump and stress was

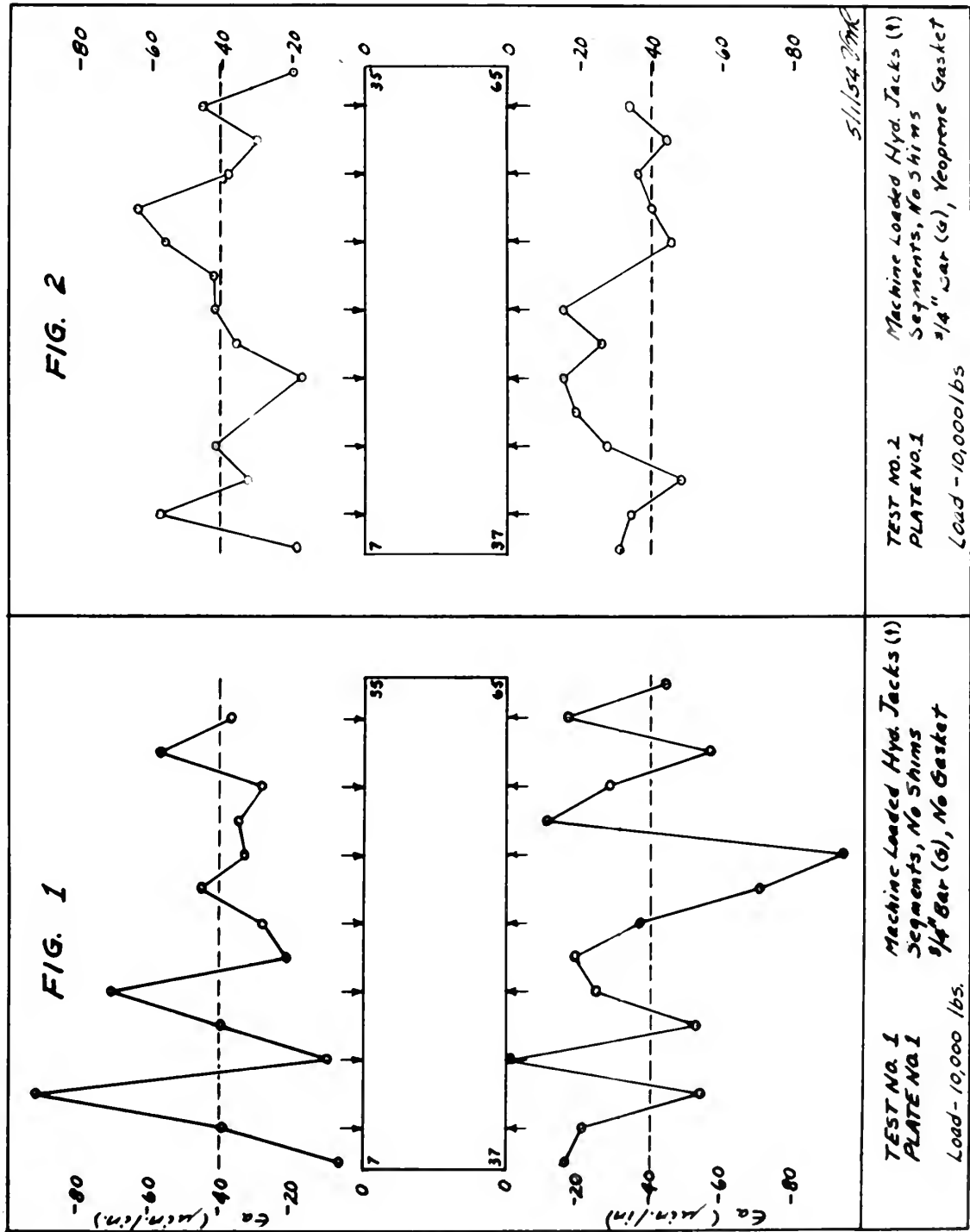
indicated between the plates and loading apparatus. Plates 1 & 2 were

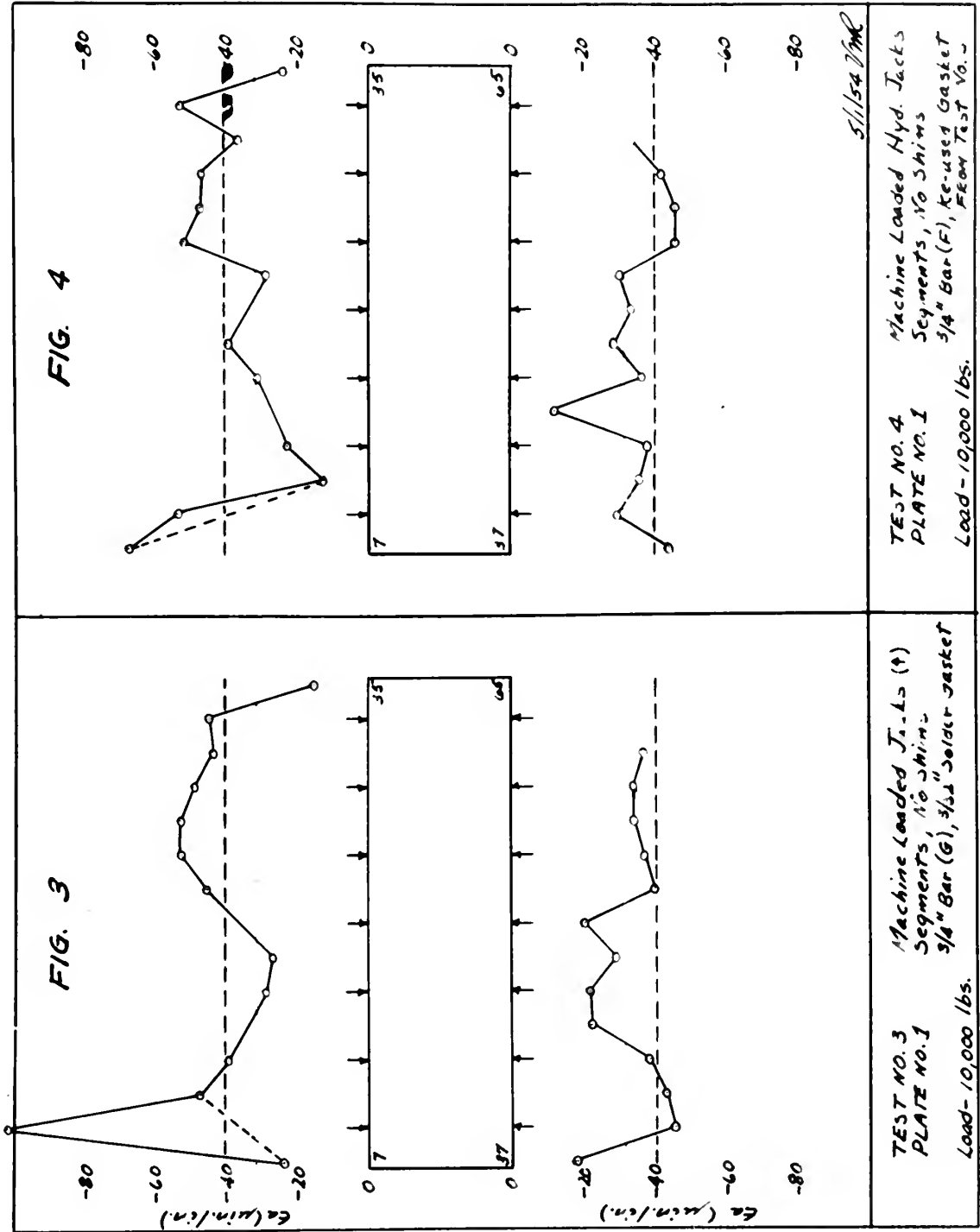
tested with double 1/16" diameter roller guides and with 1/16" side

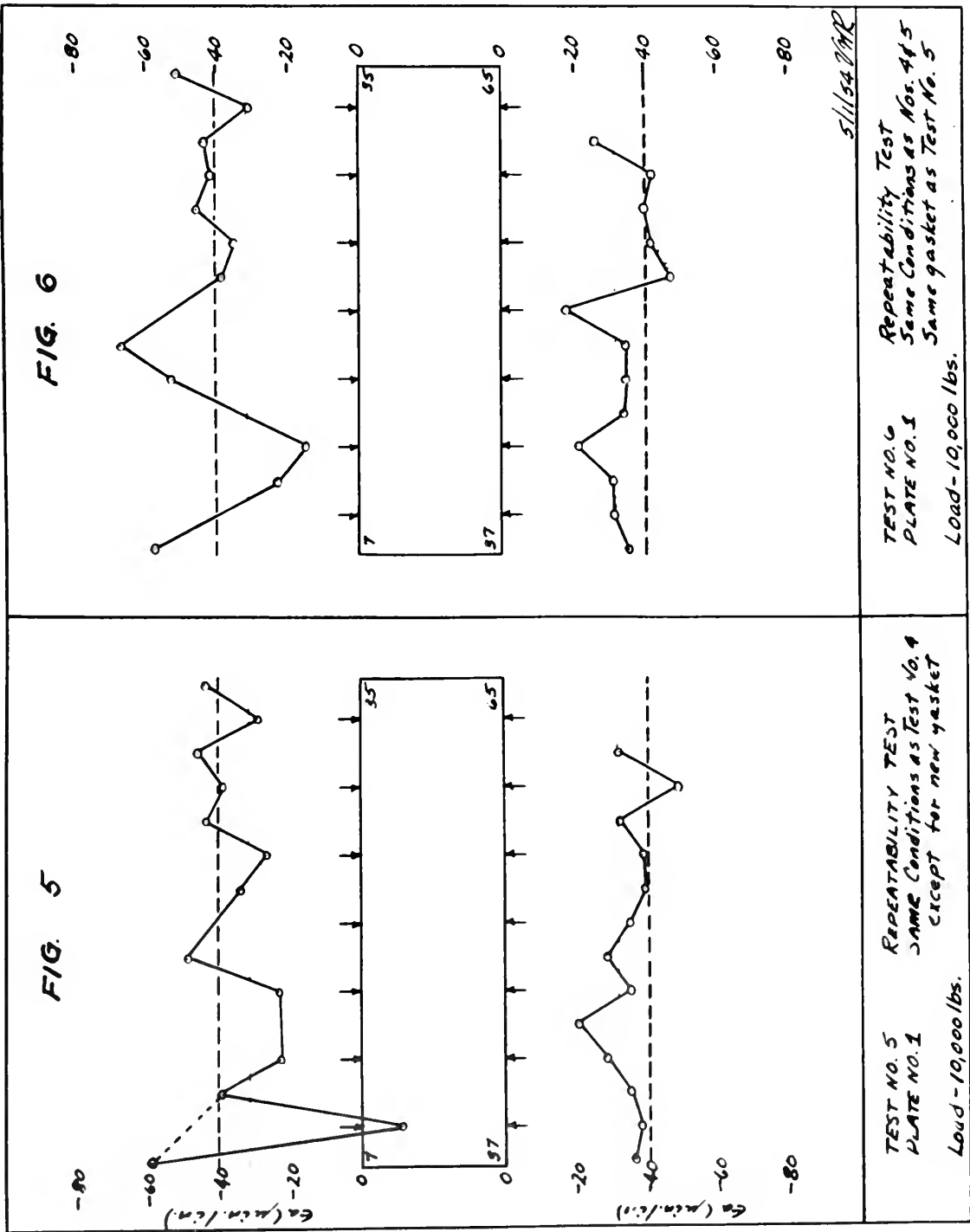
of the 1/16" loading bar toward the supports. Plates 3 & 4 were tested

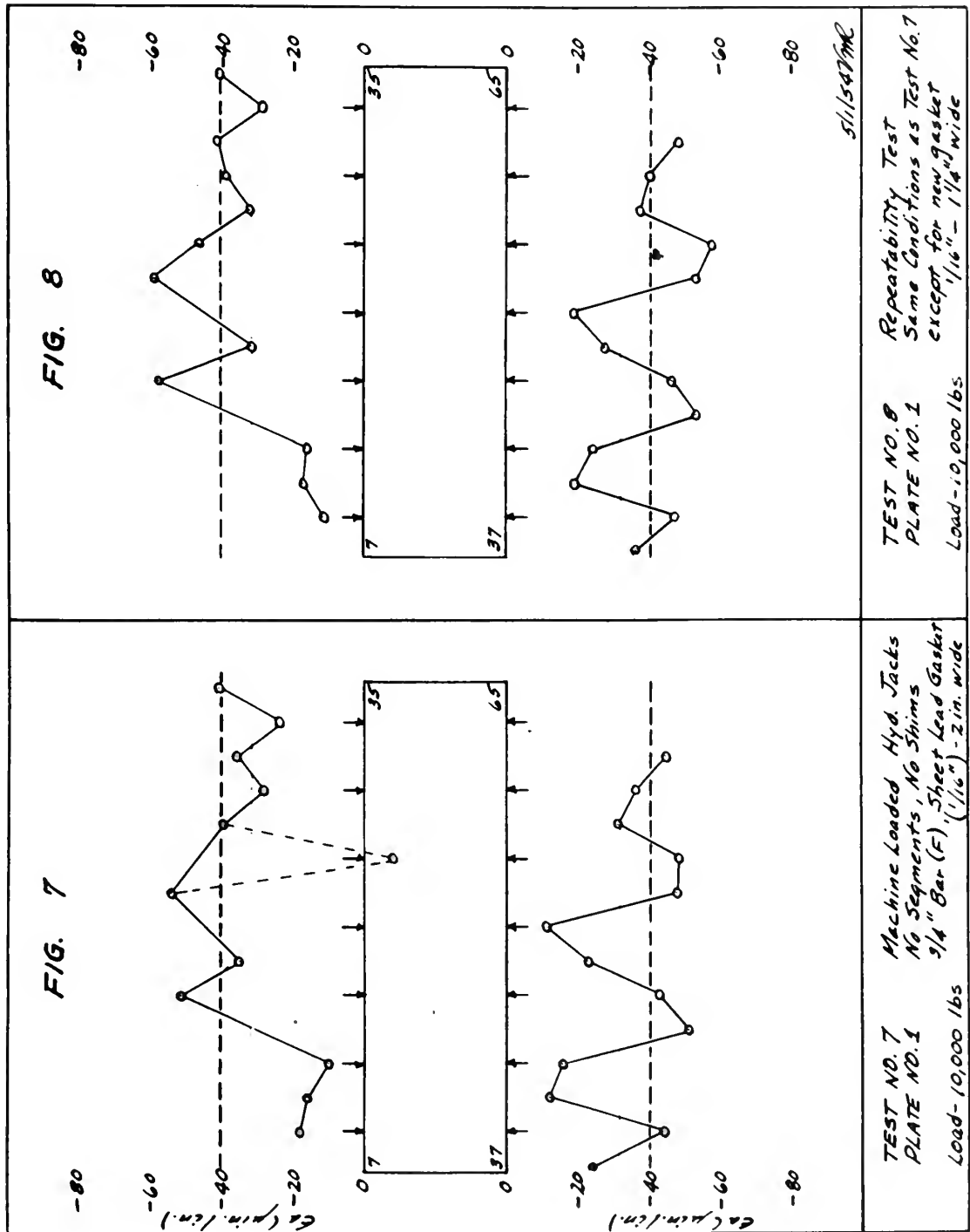
with single 1/16" diameter roller guides with the ground side of the

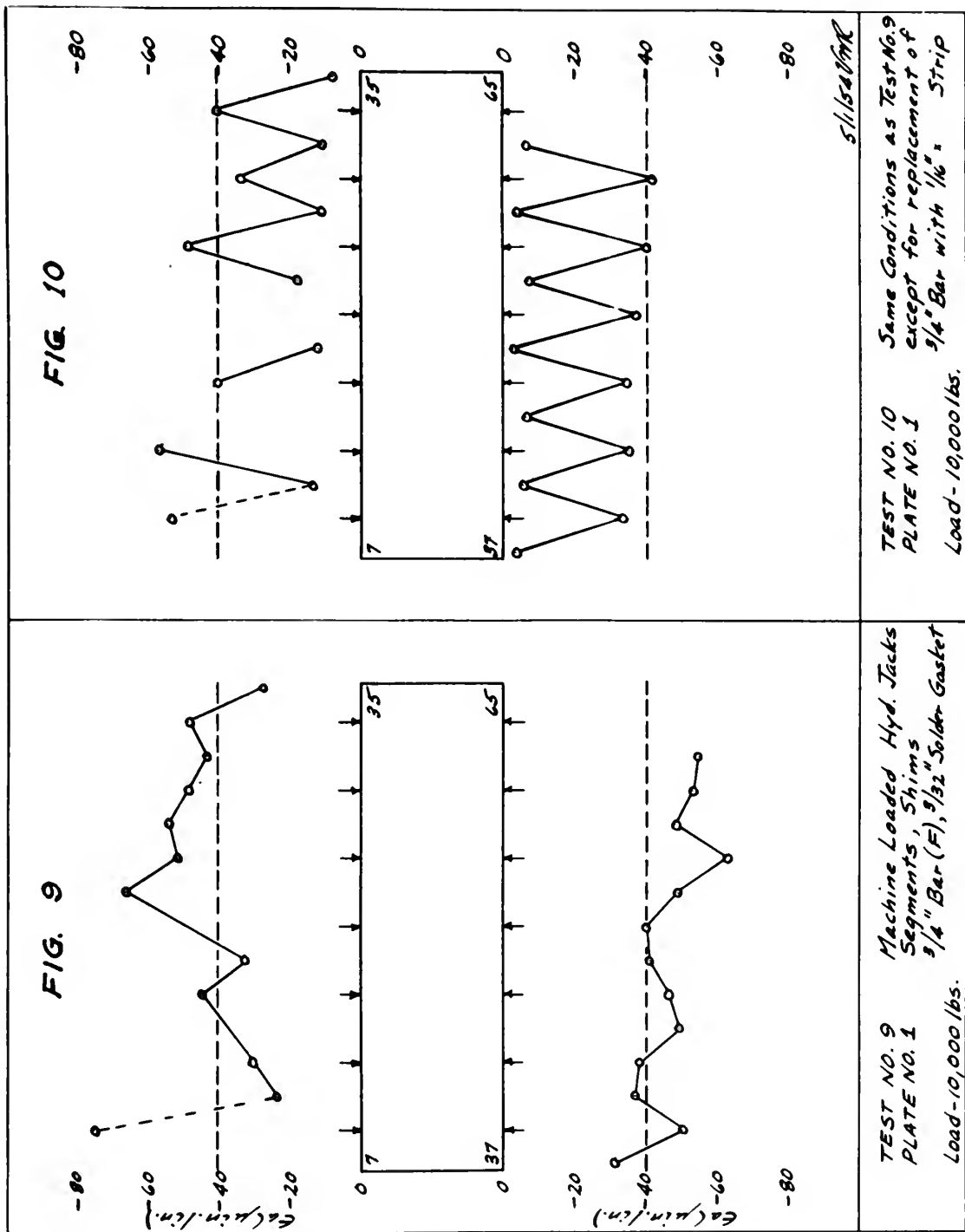
1/16" bar toward the loading apparatus.

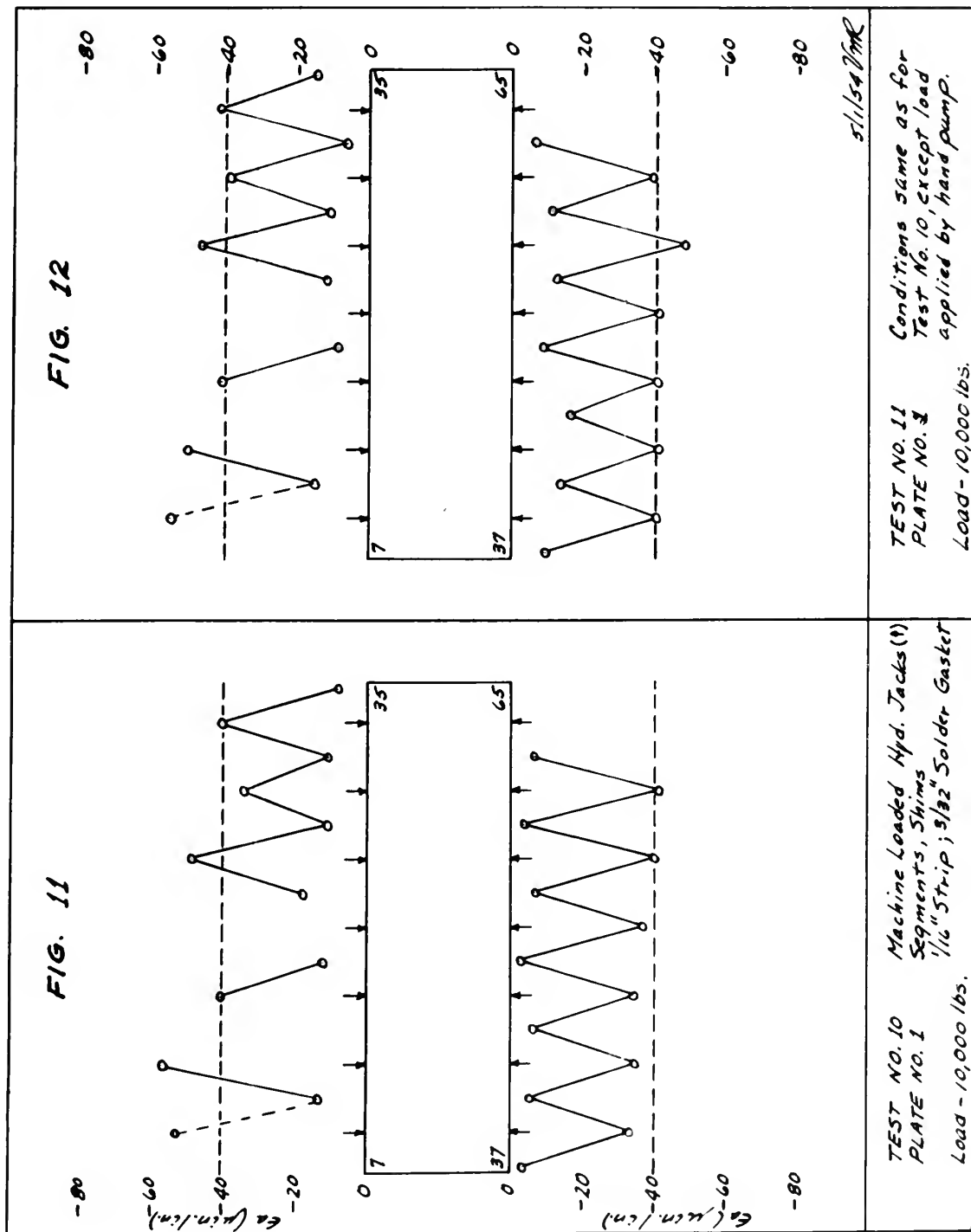


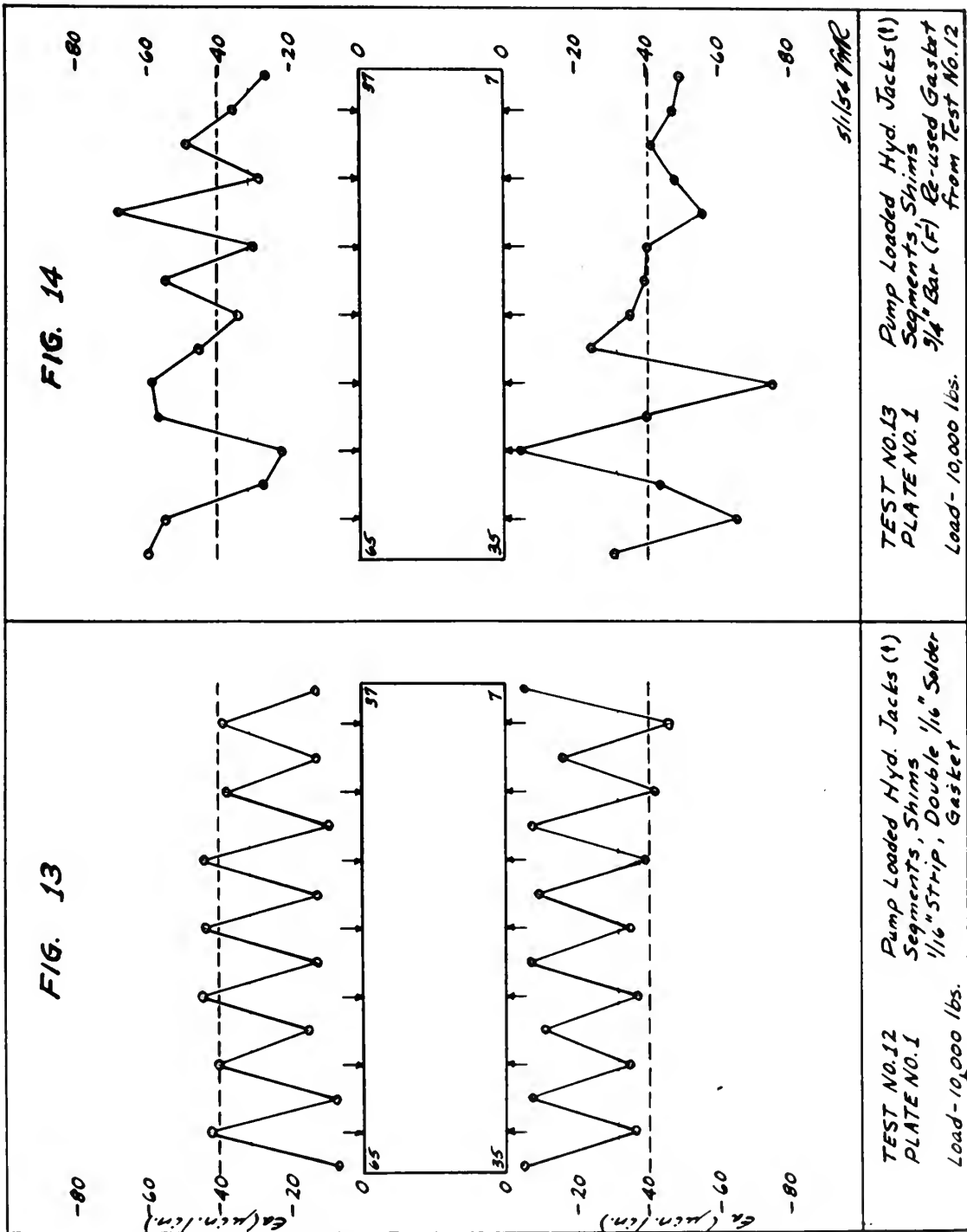


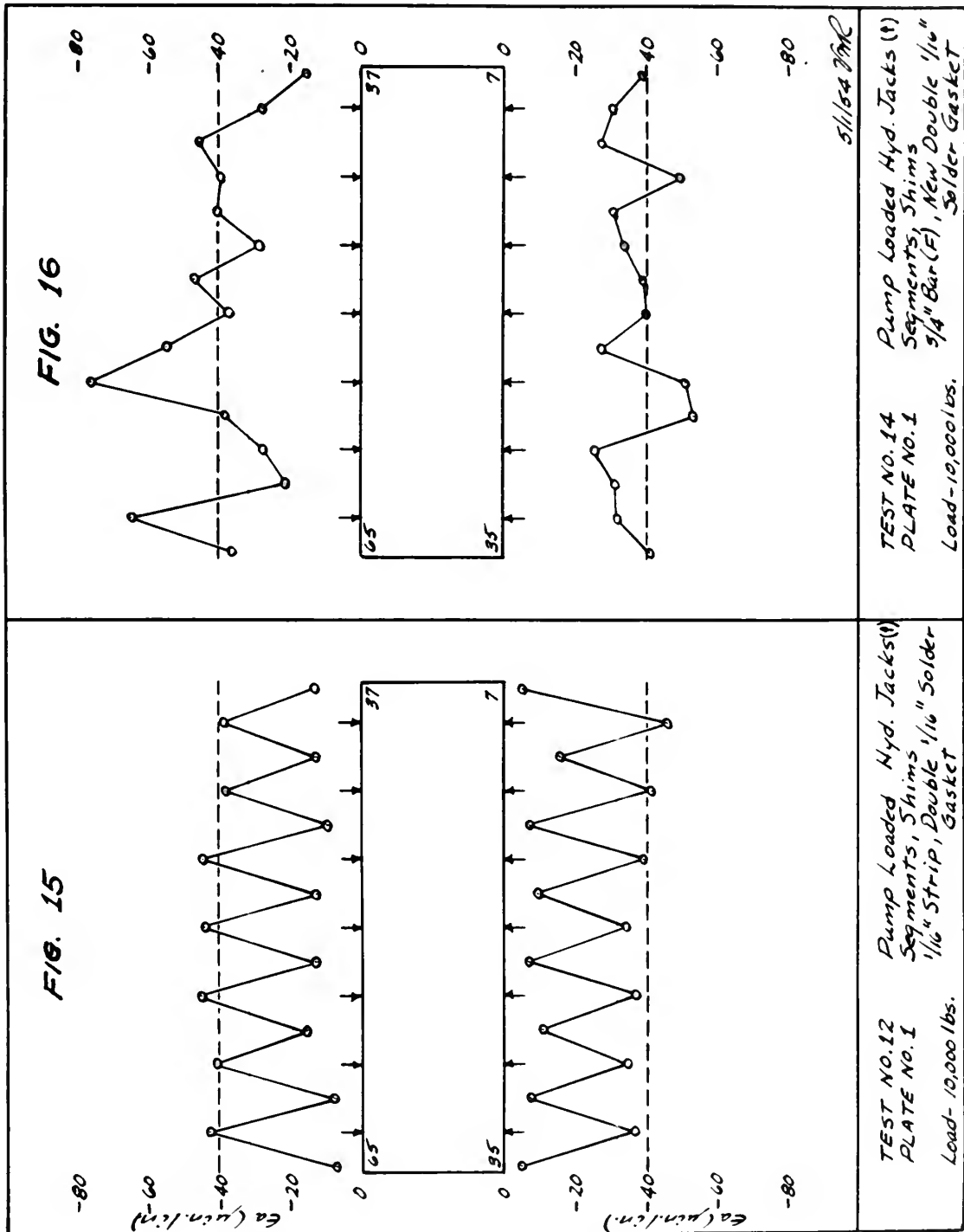


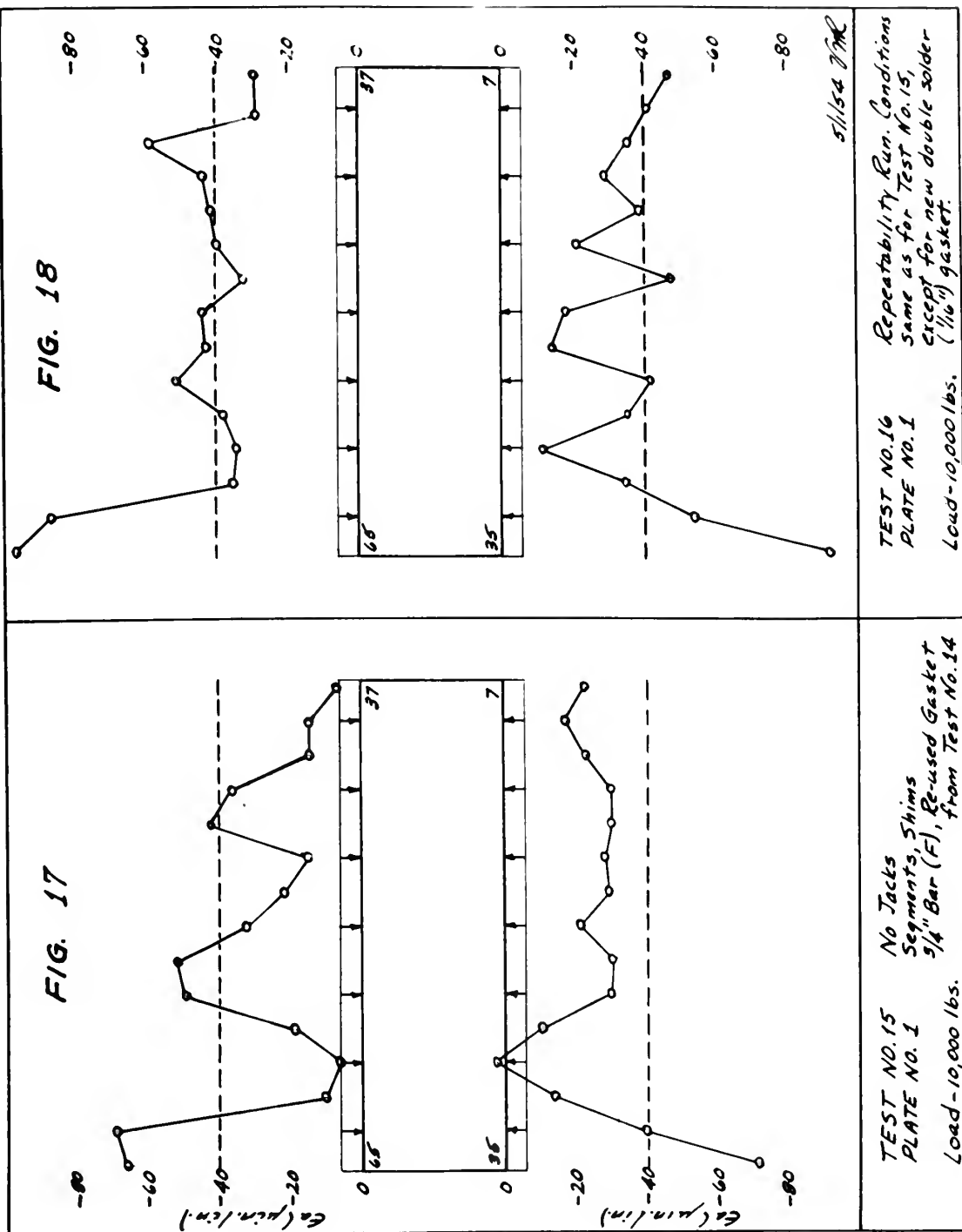












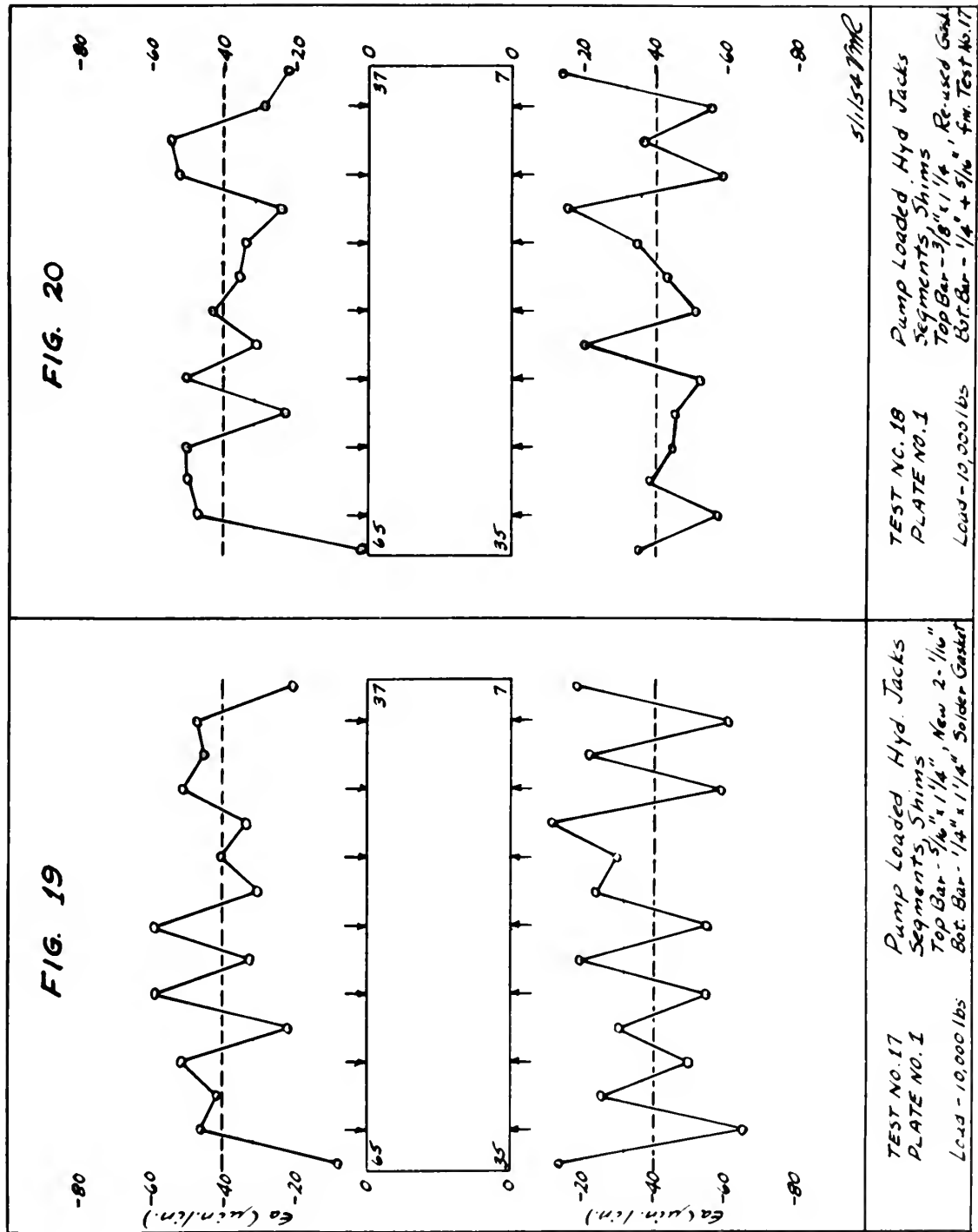


TABLE II
RESULTS of BUCKLING TESTS

Plate Data: a/b 0.237
 a/t 86.5 (av)
 E 28,300 kips/in.²
 Material: Mild steel (1020 ship plate)
 Boundary Conditions: Single support on all four edges.

Plate No.	Critical Strain Gage Location from Plate Center*	Initial Deflection (inches)	t (inches)	Ultimate Load (Kips)
1.	8.04" left 1.32" up	0.085	0.1535	35.0 36.2 **
2.	10.06" left on center line	0.057	0.1545	29.5
3.	at center	0.009	0.1545	32.5
4.	at center	0.071	0.1540	33.5

* Pair of gages on opposite sides of the plate and nearest the maximum deflection of plate under load. Long axis of plate is horizontal.

** Ultimate load after re-straightening and after many stress cycles to loads below the ultimate.

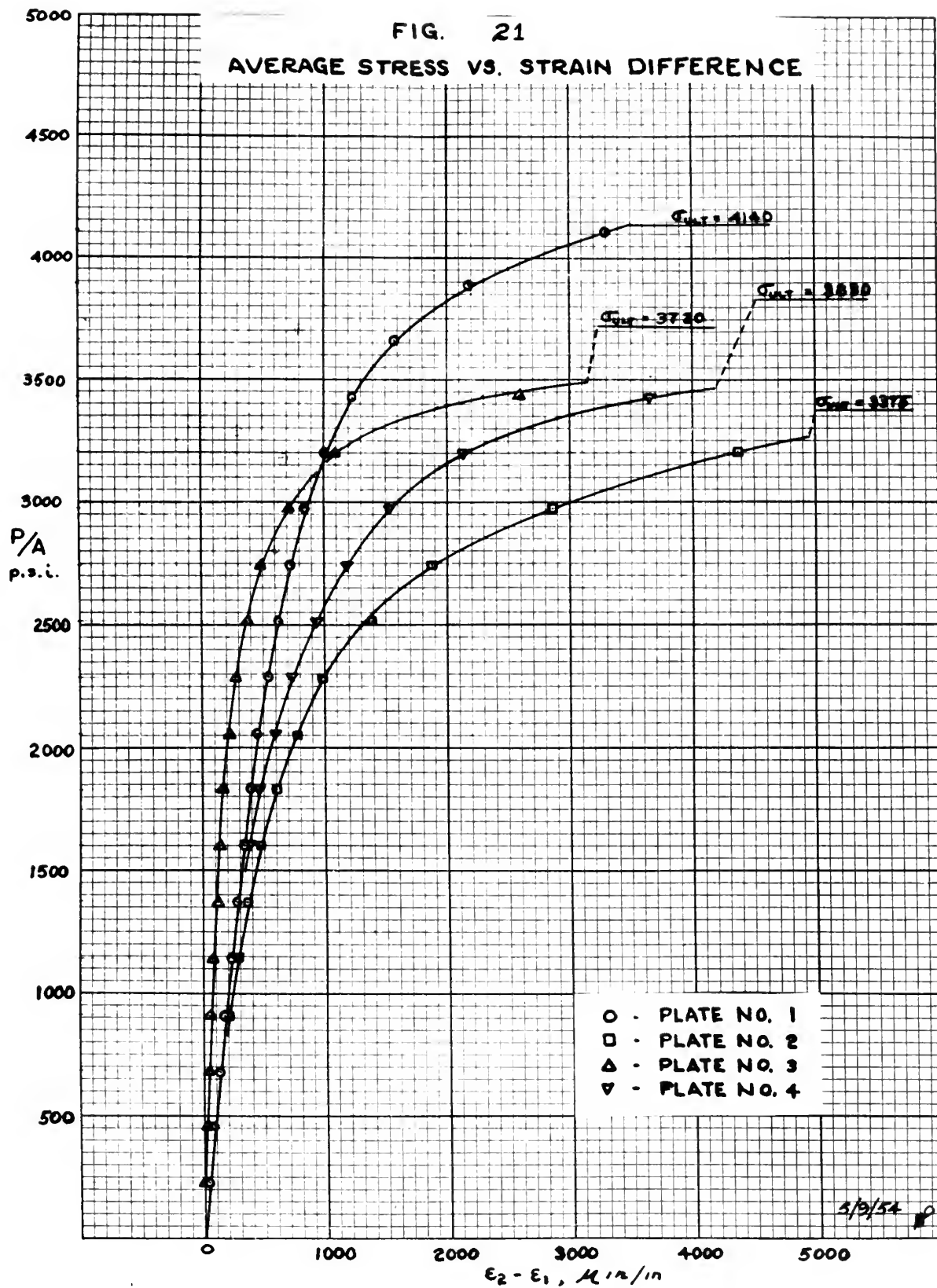
TABLE II

MECHANICAL PROPERTIES

Plate Data: 0.23%
 0.2% (m)
 50,000 psi
 Material: 7075-T6 Aluminum
 Boundary Conditions: Simple supports at 1/4 and 3/4 points

Plate No.	Location from Plate Center	Initial Deflection (inches)	Final Deflection (inches)	Displacement (inches)
1.	1/4" Left	0.000	0.000	0.000
	1/4" up			
2.	1/4" Left on Center Line	0.001	0.001	0.001
3.	at center	0.000	0.000	0.000
4.	at center	0.000	0.000	0.000

* This is based on average value of 10 plates and standard deviation of 0.001 inches.
 Plates are horizontal.
 The ultimate load at first re-arranging was about 50,000 psi.
 Changes in loads below the ultimate.



IV. DISCUSSION OF RESULTS

A. Achievement of Uniform Stress

1. General

Figures 1 to 20 represent the results of an effort to obtain an acceptable stress distribution along the loaded edge of the test plate. Test No. 1 (Fig. 1) indicated immediately that the equipment was not performing as desired. The values of the average strains did however tend to vary about the mean calculated strain indicated by the dashed line in Figs. 1 to 20 inclusive. Subsequent tests are attempts to isolate various causes for the wide variation in strain. It must be admitted that the results of these further tests were not completely satisfactory. Fairly wide strain variation continued to exist in all of the tests. A summary of comparison of average observed to average computed strains and percent deviation for the various tests appears in Table IIIA, Appendix C. It may be said however that in general the average line of the plotted distribution of the observed strains remained parallel to the loaded edge. The necessity of using the hydraulic jacks has not been clearly demonstrated here. Test Nos. 15 & 16 (Figs. No. 17 & 18) show scatter not far different from other tests except that a load concentration appeared on one "a"-edge. Such results however depend on the accuracy to which the I-beams can be shimmed into a parallel position. Under heavier loads that were not needed in these tests but which will be required for completion of the testing program, the local stress concentrations produced by the beam shims may affect the I-beams locally and destroy the original alignment. Such action was actually observed when the I-beams were originally set up and placed in

A. Adjustment of Uniform Stress

1. General

Figure 1 to 5 represent the results of an effort to obtain an acceptable stress distribution along the loaded edge of the test plate. Test No. 1 (Fig. 1) indicated immediately that the equipment was not performing as desired. The values of the average stresses did however tend to vary about the mean calculated stress indicated by the loading line in Fig. 1 to 5 inclusive. Subsequent tests are necessary to isolate various causes for the wide variation in stress. It must be admitted that the results of these further tests were not completely satisfactory. Fairly wide stress variation continued to exist in all of the tests. A summary of comparison of average stresses to average computed stresses and percent deviation for the various tests appears in Table III, Appendix C. It may be said however that in general the average line of the plotted distribution of the observed stresses remained parallel to the loaded edge. The necessity of using the hydraulic jack has not been clearly demonstrated here. Test No. 1 & 2 (Figs. No. 1 & 2) show scatter not too different from other tests except that a load concentration appeared on the "a"-edge. Such results however depend on the accuracy to which the load was set at desired load a parallel position. Under certain loads that were not needed in these tests but which will be required for completion of the testing program, the local stress concentration produced by the beam alone was offset the I-beam locally and thereby the original alignment. Such action was actually observed when the I-beam was originally set up and placed in

position. Also, the loads used in this part of the project were not severe enough to materially deflect the L-beams. It is this deflection which the use of the jacks was designed to overcome. It was expected that on the plates with shorter b-edge dimensions, the use of jacks would not be necessary. Based on the results of this thesis, it is felt that no conclusive statement on the future use of the jacks should be made.

2. Strain Gage Locations

The strain gage locations on Test Plate No. 1 (Fig. 1B) were placed as close to the edge of its plate as practicable as it was expected that at this location the strain variation would be a maximum. Due to the wide variations in strain observed, it is believed that further strain readings are needed from more closely spaced gages between jack positions in order to trace the reasons for these variations. It should be pointed out that where the 3/4" loading bar is used, peak strain readings do not always fall under jack locations. Also the jack foot itself (see Fig. 27) is not solid across the loading face. This may give rise to some strain variations especially when lighter loading bars are used.

It is expected that the strains at the middle of the test plate would be considerably moderated through shear action even when varying adjacent strains are recorded near the loaded edges. It is the strain at or near the center of its plate that is of primary interest when tests or buckling are performed. Further experiments should be performed to determine the validity of this assumption.

3. Performance of Hydraulic Jacks

It is known that two factors are present which could affect the

position. Also, the loads used in this part of the program were
severe enough to materially deflect the beams. It is this deflection
which the use of the finite was designed to overcome. It was expected
that on the plates with shorter beams, the use of finite
would not be necessary. Based on the results of this analysis, it is
felt that no conservative statement on the future use of the finite should
be made.

2. Strain Gage Locations

The strain gage locations on Test Plate No. 1 (Fig. 1B) were placed
as close to the edge of the plate as possible as it was expected that
at this location the strain variation would be a maximum. Due to the
edge variations in strain observed, it is believed that further strain
readings are needed from more closely spaced gages between load positions
in order to know the reason for these variations. It should be pointed
out that where the $\frac{1}{2}$ " loading bar is used, peak strain readings are not
always full width load positions. Also the full load (Fig. 1C)
is not wide across the loading zone. This may give rise to some strain
variations especially when lighter loading bars are used.
It is expected that the strain at the middle of the test plate would
be considerably reduced through shear action when varying weights
are suspended near the loaded edges. It is the desire of the user
the center of the plate that is of primary interest when data is required
are necessary. Further experiments should be performed to determine the
validity of these assumptions.

3. Performance of Specimen

It is known that the location of the specimen is very important.

uniformity of action of the hydraulic jacks. Friction forces may vary from jack to jack and probably vary considerably within one jack with changing loads. The plunger return springs in each jack may not produce identical return forces. For normal jack usage, the uniformity of the plunger return springs is of little consequence, hence it cannot be assumed that the manufacturer has taken special care to obtain such uniformity.

The results of Tests 3 to 6 (Figs. 3 to 6) could indicate that the lower jack system was performing better than the upper system since the variations in strain always appeared to be less on the lower plate edge. In order to check this indication and to check the jack performance as a whole, Tests Nos. 10 to 12 (Figs. 10, 12, & 13) were run with a loading bar 1/16" in thickness. This bar merely served to hold the loading segments in place between the jacks. Very little load distribution by this bar was expected or found. Referring to Fig. 13 it would appear that the jacks functioned uniformly. When considering that the possible error in each of the strain points plotted is of the order of ± 5 microinches per inch, these results are excellent evidence that the jacks are functioning properly. The low order of the readings compared to the computed average strain has no particular significance here since the strain readings under each jack location are also under the hollow part of the jack foot. Maximum readings would occur about one and one-half inches on either side of the present gage location depending precisely on the relative position of each segment in the critical area.

4. Effects of Casquets

A comparison of Figs. 1, 2, 3, & 16 can be made to study the effect

uniformity of action of the individual factors. The action of each factor was very
 from each to each and probably very considerably within each of the
 chemical factors. The physical factors appear to each have had some
 effect on the chemical factors. For example, each factor, the uniformity of
 the physical factors appears to be of little consequence, because it cannot
 be assumed that the chemical factors had uniform action on each of the
 uniformity.

The results of these 1 to 6 (Fig. 1) are shown in Table I. The
 lower factor system was particularly uniform when the upper system was the
 variation in which always appeared to be from the lower factor only.
 In order to check this uniformity and to check the lower factor system as
 a whole, these two, 10 to 12 (Fig. 1, 2, 3) were run with a constant
 but 1/10" in thickness. These two were run to check the uniformity of
 action in which between the factors. They also had a constant of 1/10"
 but was expected or found. Interacting to Fig. 1, it would appear that
 the factor thickness was uniform. When considering each of the points over
 in each of the series points plotted is at the center of 2 measurements
 per inch, these results are consistent with the factor and 1/10"
 thickness property. The last set of the thickness property is the constant
 average value has no particular significance here since the factor is
 large factor each factor thickness was also noted the factor part of the
 foot. Maximum thickness would occur about one and one-half inches or
 either side of the present page location depending on the
 relative position of each segment in the vertical plane.

1. Effects of factors

A comparison of Figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493, 494, 495, 496, 497, 498, 499, 500, 501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 845, 846, 847, 848, 849, 850, 851, 852, 853, 854, 855, 856, 857, 858, 859, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877, 878, 879, 880, 881, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 903, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 917, 918, 919, 920, 921, 922, 923, 924, 925, 926, 927, 928, 929, 930, 931, 932, 933, 934, 935, 936, 937, 938, 939, 940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 950, 951, 952, 953, 954, 955, 956, 957, 958, 959, 960, 961, 962, 963, 964, 965, 966, 967, 968, 969, 970, 971, 972, 973, 974, 975, 976, 977, 978, 979, 980, 981, 982, 983, 984, 985, 986, 987, 988, 989, 990, 991, 992, 993, 994, 995, 996, 997, 998, 999, 1000.

of placing gasket material along the loaded edges of the plate. From Figs. 1 & 2 it can be seen that the use of a neoprene gasket materially reduced the strain variation. Comparing Fig. 3 with Fig. 2 it appears that the use of a single solder wire gasket further reduces these variations to a small extent. Figs. 3 and 16 show little change resulted from using a double rather than a single solder strip. This comparison is complicated by the fact that the flat side of the loading bar was used in Fig. 16.

It seems evident that part of the strain variations are due to local unevenness in the plate or loading bar and that the effect of these points on the strain distribution can be reduced through the use of a gasket material. The solder gasket appears to be slightly more beneficial than a neoprene gasket although this difference may have disappeared entirely if a thicker neoprene gasket were used. The results also tend to indicate the advisability of using new gasket material for each test.

5. Size and Shape of the Loading Bar

A comparison of Figs. 15 and 16 indicated that the presence of the $3/4"$ thick loading bar quite logically tends to bridge the gap between the points of load application under each jack but in so doing introduces local strain variation of considerable magnitude.

An attempt was made to determine if an optimum bar size existed between the two extreme sizes used in Figs. 15 and 16 by inserting bars of intermediate size. (See Figs. 19 & 20.) The results of these tests seem to indicate that the thicker bar should give better results but that the $3/8" \times 1\ 1/4"$ bar gives acceptable results. Since the plate tested uses the widest jack spacing of all the plates in the test program,

[illegible]

It seems evident that part of the above mentioned items were not
local movements in the place of loading but that the items in ques-
tion were not shipped through the port of New York but were shipped
directly to the United States. The United States appears to be directly
concerned with the items in question although the items may have been
shipped to the United States through the port of New York. The items in
question were shipped to the United States through the port of New York.

2. The main body of the letter was
a comparison of the two. It was in substance that the
"A" was better than the "B" in every respect
the points of local significance were not to be
local areas outside of the immediate vicinity.
In summary, it was stated that the
between the two areas was not in the
of importance. (See page 10 of the report)
to indicate that the situation was not
the "A" was given considerable weight.
was the highest level of the local area.

difficulties of bridging the gap between jacks will decrease on the remaining plates.

When using the $3/4"$ loading bar a choice existed on which face to use, flat or grooved. During the early tests it was felt that the position of the segments in the groove may have given rise to local strain variations. Hence, the flat side of the bar was used in subsequent tests. A comparison of Figs. 3 & 4 however shows that little difference in strain variation can be attributed to this effect. Actually during the buckling tests, it was found that it is necessary to use the grooved side of the loading bar to prevent lateral movement of the loaded edges when high deflections occur.

6. Effect of Shims

A study of Figs. 4, 5, 9, & 16 seems to indicate that the presence of shims has little effect on the strain variation. However it is felt that shims are necessary when conducting buckling tests. The milled grooves in the loading segments are approximately $1/32"$ wider than the plate thickness. The presence of the shims decreases the possibility of eccentric loading on the plate by insuring that the plate edge is centered at or under the radial center of the loading segment. It further aids in straightening the plate edge when the grooved side of the loading bar is used.

7. Effect of Loading Segments

Two tests (Figs. 7 & 8) were run without segments but with a sheet lead gasket between the plate and the loading bar. Strain variations for these tests were generally worse than for other comparable runs. It is

distinction of subjects of the same kind, and the

following results.

When the subjects were asked to judge the

value of the subjects, the results were as follows:

Results of the subjects of the same kind, and the

results of the subjects of the same kind, and the

results of the subjects of the same kind, and the

results of the subjects of the same kind, and the

results of the subjects of the same kind, and the

results of the subjects of the same kind, and the

of the subjects of the same kind, and the

of the subjects of the same kind, and the

A study of the subjects of the same kind, and the

of the subjects of the same kind, and the

that there was a significant difference between the

groups in the subjects of the same kind, and the

these results. The results of the subjects of the same kind, and the

of the subjects of the same kind, and the

considered as a whole, the results of the subjects of the same kind, and the

further study of the subjects of the same kind, and the

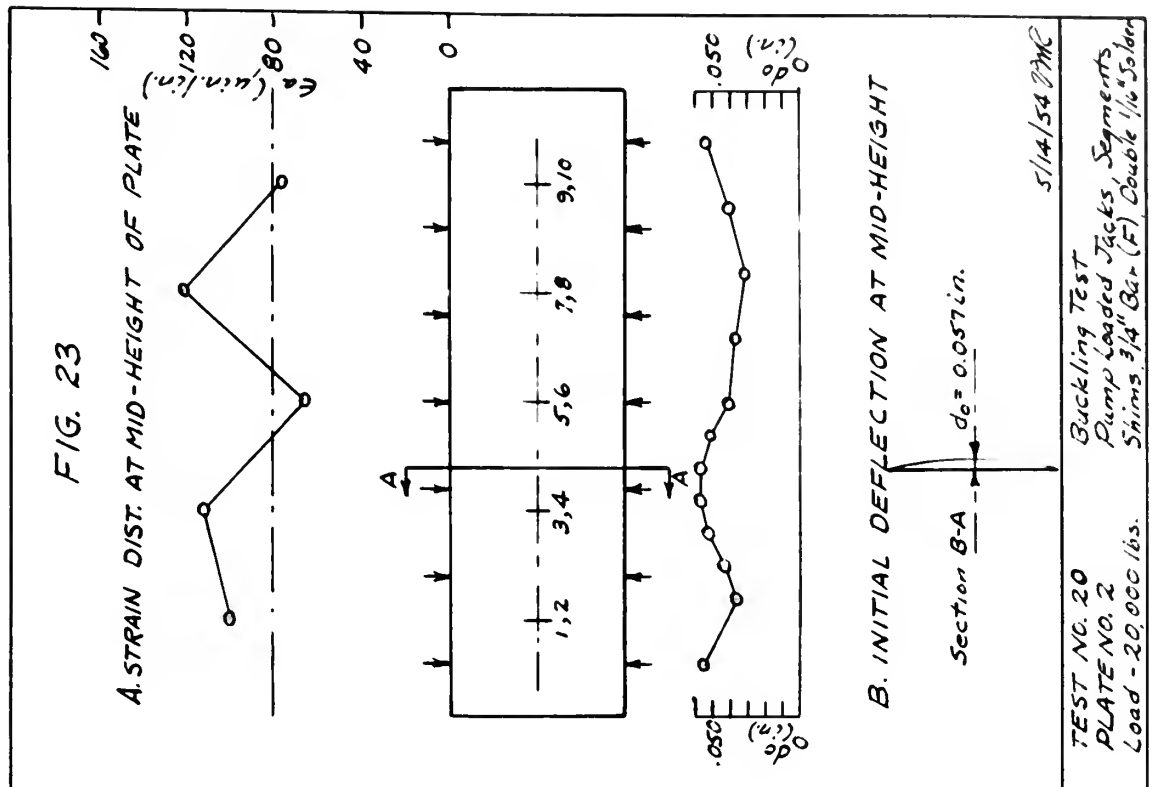
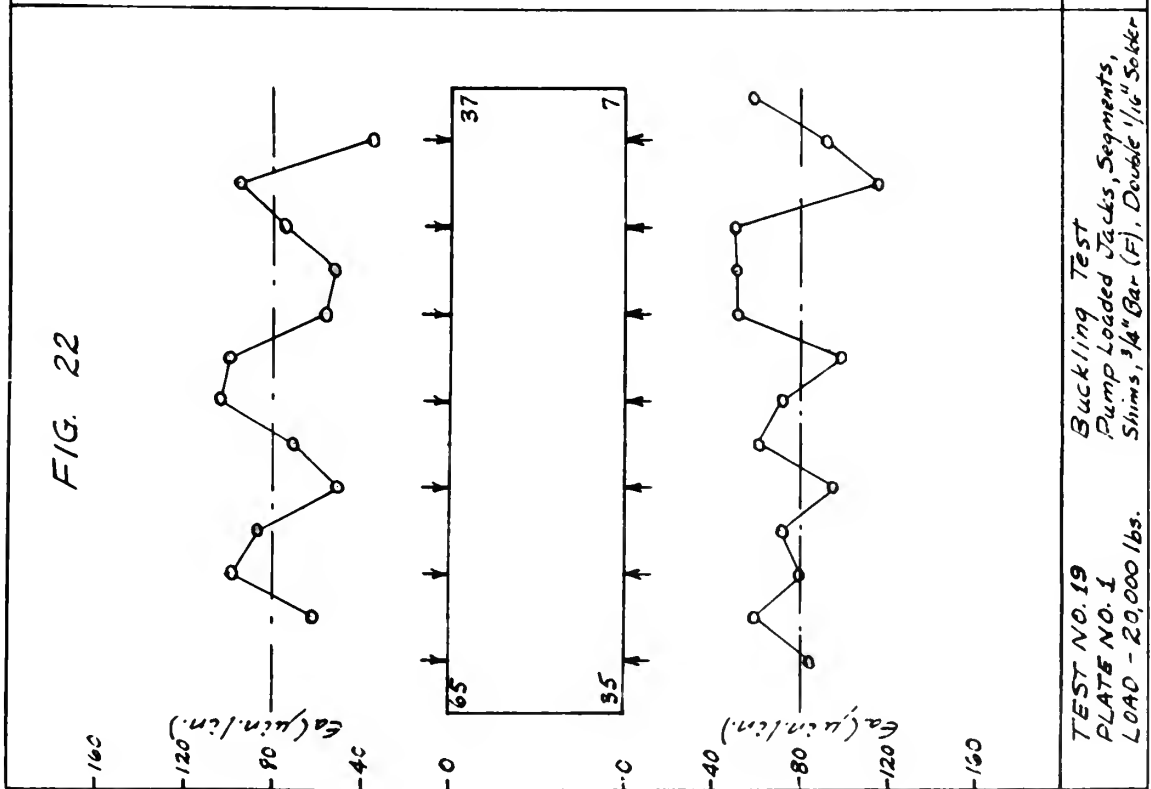
the results of the subjects of the same kind, and the

of the subjects of the same kind, and the

the results of the subjects of the same kind, and the

lost interest between the subjects of the same kind, and the

these results were generally in line with the results of the subjects of the same kind, and the



difficult to separate the effects of the change in gasket material and the effect of the segments. The combination of effects however causes higher strain variations. It was felt that the gasket material used here (lead roof flashing) seems too stiff a material and its effect masked that of the segments.

B. Buckling Data

1. General

The comparison of the critical stress of the plate specimens with that of the theoretical predictions (See Table IIIB) was most gratifying and constituted an important phase in the overall evaluation of the test equipment. Although evidence of a concrete nature is lacking these results tend to support the view that both the stress distribution and the achievement of simple support on the plate edges was satisfactory at least to a practical degree. Further tests should be run to support this view. In particular a separate test perhaps without "a"-edge supports should be run to check the action of the segments to determine if rotational restraint is present. It is felt that fairly high loading would have to be developed before any appreciable resisting moment could develop.

The results of the buckling tests do not completely allay the apprehensions developed under the discussions of uniform edge loading. These results do, however, provoke the thought that the degree of uniformity necessary for uniform buckling results is not as stringent as heretofore supposed.

2. Effect of Initial Deflections

It will be noted in the results (Table II), test Plate No. 1 failed

at a considerably higher load than the remaining specimens. It should also be noted that the original ultimate load before the plate was straightened was 1200 lbs. lower than the final ultimate load. Unfortunately too few strain readings were recorded preceding the first ultimate load on which to base an estimate of the critical load. It is believed however that the difference in the first and final ultimate loads can be explained at least in part by the fact that in restraightening the plate, a complex contour of the plate surface was introduced. It is believed that the strength of such a plate is increased depending on the amount and character of the departure of the initial unfairness from the final deflected shape of the plate prior to yielding. With simple support such shape is usually sinusoidal in form. No particular correlation between initial maximum deflection and final ultimate or buckling loads could be found with the remaining plates. This tends to support the belief that in thin plates character of the initial contour is an overriding effect when considering the strength of such plates.

3. Action of Wide Thin Plates Under Edge Compressions

A comparison of Euler's column formula and the solution of the plate equation for the critical stress indicate that the only difference in form except for the Poisson effect in plates is the value of k in the solution for plates. For wide plates this value is very close to one. Hence one would expect wide plates to behave very much like columns up to the critical stress. An inspection of Figs. 24, 25, & 26 indicates that its test plates behaved very much like eccentrically loaded columns where the deflection grows continually under increasing load. Under such conditions it is somewhat an artificiality to attempt to define a critical

as a considerably higher load than the nominal specified load.

also be noted that the original ultimate load before the plate was

straightened was 1800 lbs. lower than the final ultimate load. This

finally too low ultimate loadings were recorded because the final

ultimate load at which to have a maximum of the plate was 1800 lbs.

believed however that the difference in the final and ultimate

loads can be explained as being due to the fact that the

ing the plate, a complete section of the plate was lost.

It is believed that the strength of the plate is increased by the

on the amount and direction of the deflection of the plate which

from the final deflected shape of the plate prior to the

single upward bend shape is usually obtained by the

correlation between initial and final deflection and

breaking loads could be found with the existing plate

support the belief that in some cases deflection of the plate

is an overriding factor when considering the effect of

2. Action of the plate under the load is considered

A comparison of the load and deflection curves for the

plate specimen for the two cases is shown in Figure 1.

in form except for the location of the load in the

specimen for plates. In the first case the load is

applied at the center of the plate and in the second

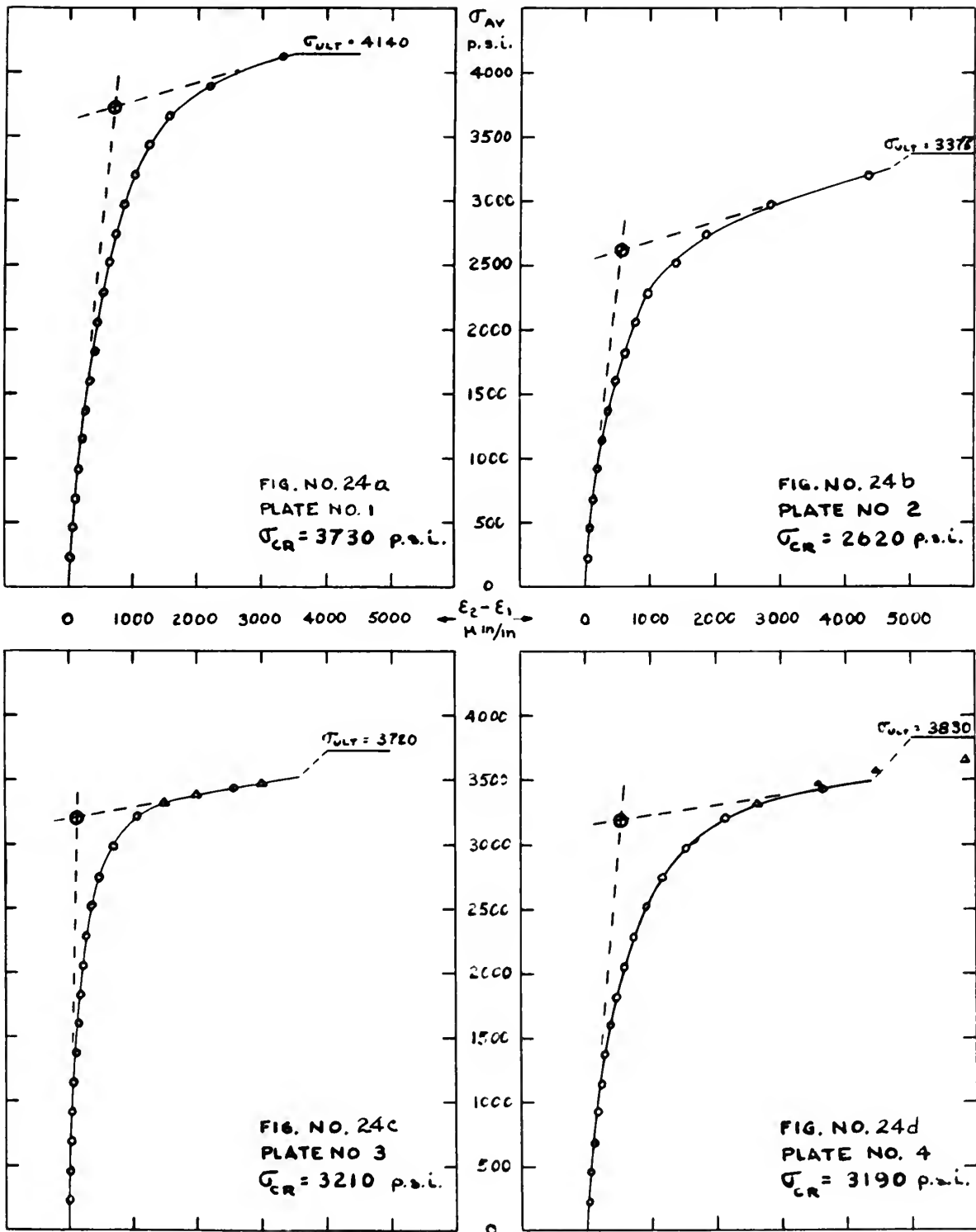
the original shape. In the second case the load is

the load is applied at the center of the plate

the deflection curve is shown in Figure 2.

Figure 3 is a schematic diagram showing the

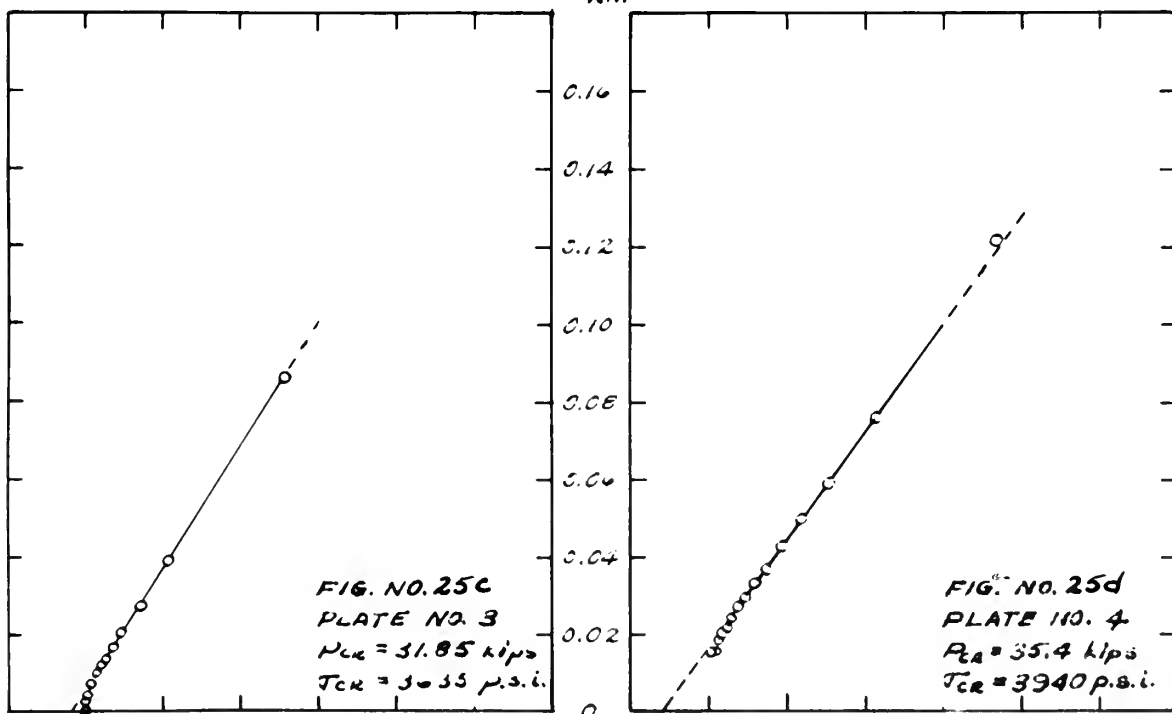
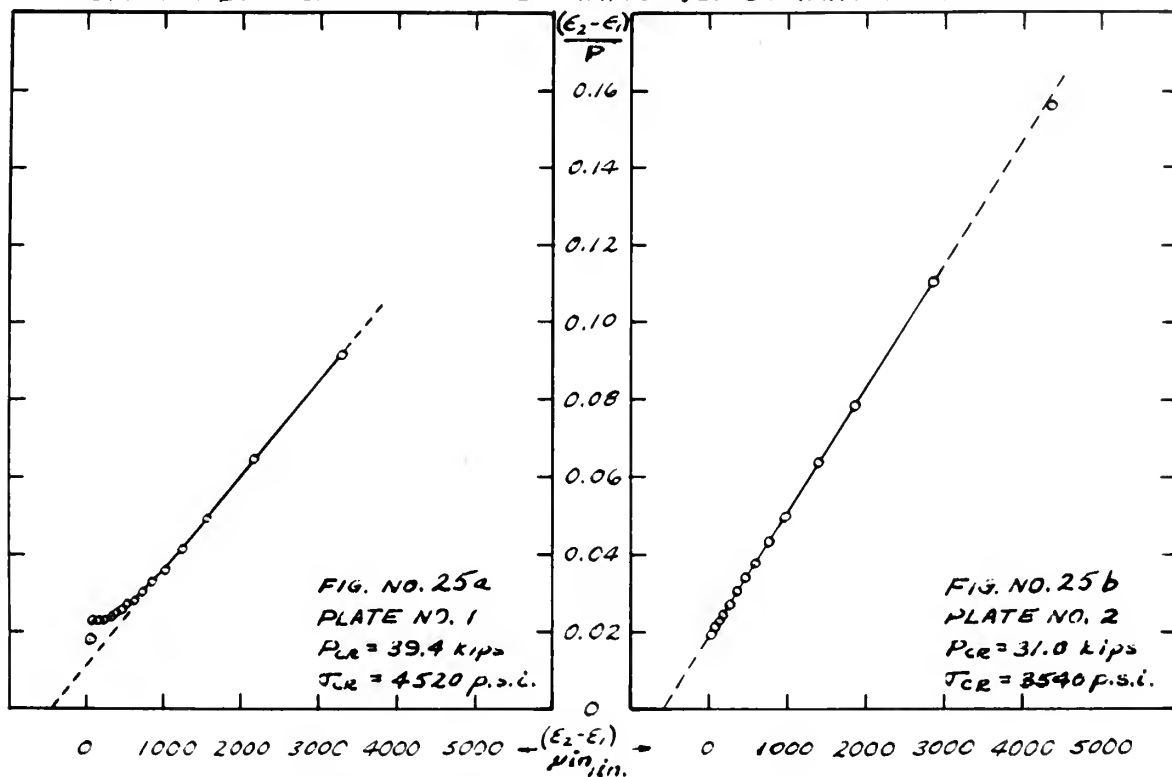
FIG. 24
STRESS VS. STRAIN DIFFERENCE



DETERMINATION OF σ_{CR} BY TOP-OF-THE-KNEE METHOD

5/13/54 *HH*

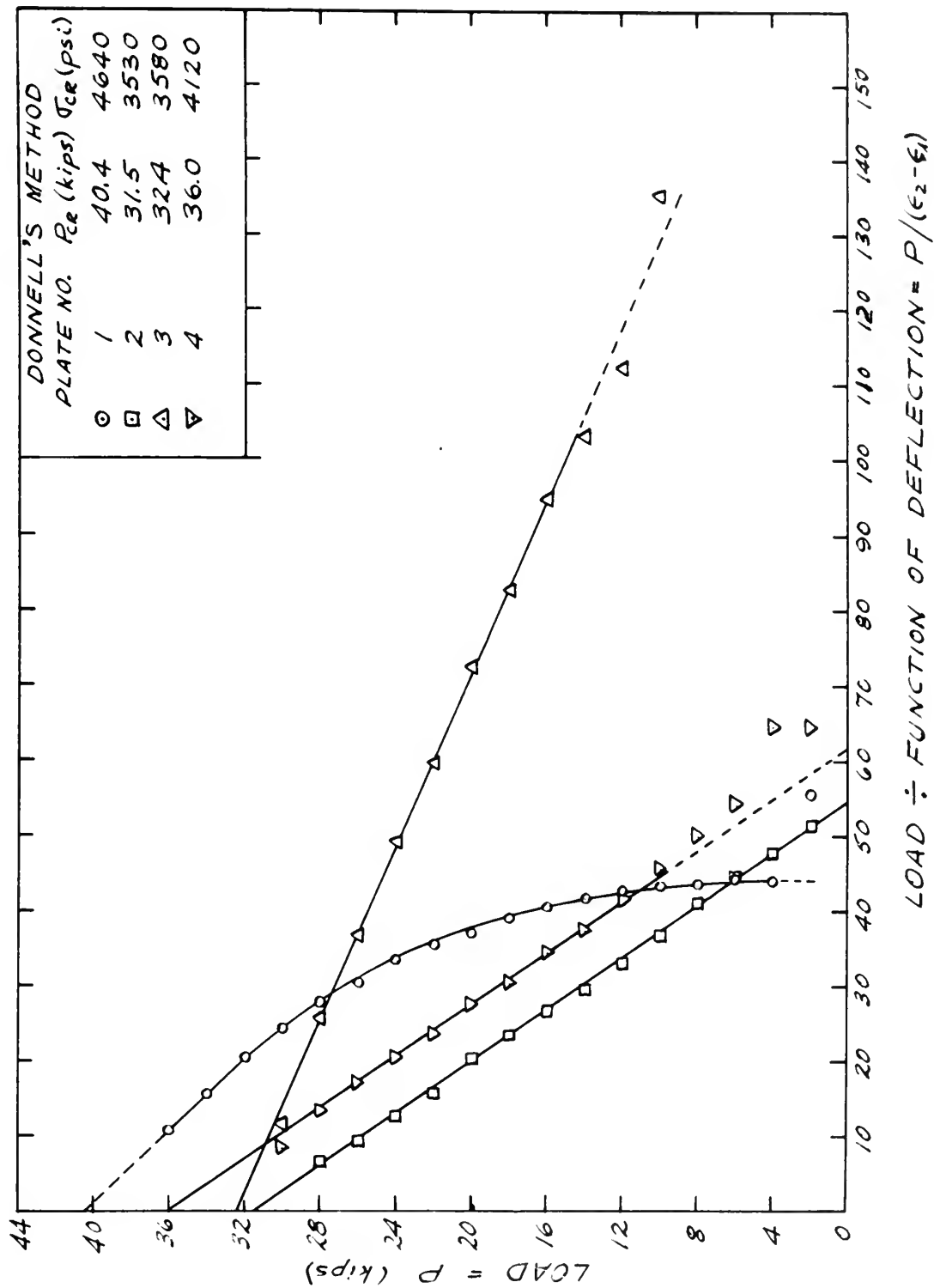
FIG. 25
STRAIN DIFFERENCE - LOAD RATIO VS. STRAIN DIFFERENCE



DETERMINATION OF T_{cr} BY SOUTHWELL'S METHOD

5/14/54 M.V.

FIG. 26
LOAD VS. LOAD-DEFLECTION RATIO



buckling load. However the necessity exists if comparison to the theoretical buckling stress is to be made. The significant load however, in this case is the ultimate load, the occurrence of which is probably coincidental with the development of a plastic hinge in an element of the plate. Bleich [Ref. 8, p. 475] gives a predicted value for the ultimate stress in wide plates based on Marguerre's large deflection theory. Such predicted values based on $\bar{\sigma}_y$ and $\bar{\sigma}_x$ lead to absurd values for the plates tested since the assumption that the plate remains a rectangle is not valid for these plates. It is believed however that Bleich's predicted values of the critical stress for the remaining plates in the test program will be extremely valuable in alerting the experimenter to impending failure. It should be noted that the authors failed to obtain a sufficient number of readings just prior to the ultimate load on the plate. The character of the load-deflection near failure plays a large part in determining the theoretical value of the critical stress.

4. Calibration of the Testing Machine (See Appendix E).

While this topic is not strictly in the nature of a result it does have a bearing on the validity of the comparison of buckling results. The difference between the load indicated by the testing machine and that indicated by the hydraulic jack pressure at the manifold does not necessarily prove an error exists but it does admit the possibility of such an error. It is expected however that any correction if required will be small since the three gages on the machine agree very closely. Before future testing proceeds however, the testing machine should be calibrated.

buckling load. However the necessity exists if comparison to the
 theoretical buckling stress is to be made. The slight load now
 ever, in this case is the ultimate load, the occurrence of which is
 probably coincidental with the development of a plastic hinge in an
 element of the plate. Hirsch [Ref. 5, p. 417] gives a predicted value
 for the ultimate stress in thin plates based on Timoshenko's large
 deflection theory. Such predicted values based on σ and τ are used
 to obtain values for the plates tested since the assumption that the
 plate remains a rectangle is not valid for these plates. It is believed
 however that Hirsch's predicted values of the critical stress for the
 remaining plates in the test program will be reasonably accurate in
 alerting the experimenter to impending failure. It should be noted
 that the authors failed to obtain a satisfactory number of readings just
 prior to the ultimate load on the plates. The character of the load-
 deflection curve failure plays a large part in determining the theoretical
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4. Calibration of the Testing Machine (See Appendix E).

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 The difference between the load indicated by the testing machine and
 that indicated by the hydraulic jack pressure in the standards does not
 necessarily prove an error exists but it does indicate the possibility of
 such an error. It is expected however that any error of the type
 will be small since the three gages on the machine agree very closely.
 Before future testing proceeds however, the testing machine should be
 calibrated.

V. CONCLUSIONS

1. The load distribution provided by the test apparatus is not completely satisfactory; however certain lesser conclusions can be drawn.
 - a. The hydraulic jacks functioned as they were expected to, although there is not enough data at present to conclude they are necessary.
 - b. There was no general slope to the mean line of strain distribution; rather the strains varied about the computed average value.
 - c. The stiffness of the loading bar is an important factor in the load distribution and one which is subject to more study.
 - d. Factors other than the jacks produced serious strain variations as is evidenced by the fact that the strain peaks showed no consistent tendency to occur under the jacks when the heavier bars were used.
 - e. Load distribution is not markedly influenced by type of gasket and whether or not shims are used; however a new gasket should be used for each test and shims should be used to reduce eccentricity of loading.
2. Although no specific investigation was made, it is tentatively concluded that simple support was obtained, in view of the following observations:
 - a. The final buckled configuration.
 - b. The fact that the edges remained straight even after buckling, especially when the grooved bar was used.
 - c. The resultant critical stresses.

1. The land distribution provided by the test apparatus in the case of the test apparatus is not satisfactory; however, certain features can be observed.
- a. The irregularities in the distribution of the test apparatus are not satisfactory.
- b. There was no general slope to the test apparatus at the time of the test.
- c. The irregularities in the distribution of the test apparatus are not satisfactory.
- d. The irregularities in the distribution of the test apparatus are not satisfactory.
- e. The irregularities in the distribution of the test apparatus are not satisfactory.
- f. The irregularities in the distribution of the test apparatus are not satisfactory.
2. Although no specific irregularities were noted in the test apparatus, it is observed that the irregularities in the distribution of the test apparatus are not satisfactory.
- a. The irregularities in the distribution of the test apparatus are not satisfactory.
- b. The irregularities in the distribution of the test apparatus are not satisfactory.
- c. The irregularities in the distribution of the test apparatus are not satisfactory.
- d. The irregularities in the distribution of the test apparatus are not satisfactory.
- e. The irregularities in the distribution of the test apparatus are not satisfactory.
- f. The irregularities in the distribution of the test apparatus are not satisfactory.

3. The equipment is essentially satisfactory for proceeding with future testing.
4. The grooved bar should be used for buckling tests.
5. The stress distribution at the edge of the plate is not extremely critical for buckling tests.
6. The buckling and ultimate strength of wide thin plates is not a function of the maximum measured unfairness alone since the initial contour and past history of the plate may have overriding effects.
7. Due to the difficulty of keeping initial deflections small with respect to the thickness for these plates, buckling loads cannot be obtained directly but must be obtained by extrapolating the data.
8. Wide thin plates act like columns and their strength is affected but little by the presence of support at the unloaded edges.
9. Contingent upon the previous conclusions, valuable buckling data was obtained for one series of plates.
10. The theory as presented in Bleich [8] is supported, and can be used at least to predict the approximate critical loads for future experimental works.
11. Insufficient data was taken in the vicinity of the critical load.
12. Insufficient data was obtained to analyze the growth of unfairness in the plates.
13. While no conclusive evidence exists, there is reasonable doubt as to the accuracy of calibration of the testing machine.

3. The equipment is essentially satisfactory for present and future testing.
4. The groove bar should be used for buckling tests.
5. The stress distribution at the edge of the plate is not extremely critical for buckling tests.
6. The buckling and ultimate strength of wide thin plates is not a function of the maximum measured deflection from the initial contour and past history of the plate may have overriding effects.
7. Due to the difficulty of keeping initial deflections small with respect to the thickness for these plates, loading loads cannot be obtained directly but must be obtained by extrapolating the data.
8. Wide thin plates act like columns and their strength is affected but little by the presence of supports at the unloaded edges.
9. Consequent upon the previous conclusions, reliable buckling data was obtained for one series of plates.
10. The theory as presented in Exhibit [1] is supported, and can be used at least to provide the approximate critical loads for future experimental work.
11. Instabilities were seen in the vicinity of the critical load.
12. Instabilities were not observed to analyze the growth of instabilities in the plates.
13. While no conclusive evidence exists, there is reasonable doubt as to the accuracy of calculation of the testing machine.

VI. RECOMMENDATIONS

1. Further investigation of the stress distribution should be made, and attempts made to improve it if necessary, using a plate with a larger thickness and smaller a/t ratio. Strains should be measured at one edge (as before), at the center line, and in detail between two adjacent jacks both at the edge and the centerline to determine more completely the nature of the distribution.
2. Further tests should be conducted to compare the operation of the apparatus when the hydraulic jacks are used and when the loading bar bears directly upon the I-beam.
3. Column tests should be run (no "a"-edge supports) to determine whether simple support is obtained at the "b" edge.
4. The test plates will be more accurately cut if sandblasting is done before the edges are machined instead of after.
5. Bleich's theory should be utilized to predict the critical load for future experimental work.
6. More data should be obtained in the region of the critical load.
7. A dial gage with a longer travel is necessary to measure the growth of unfairness as the plate is loaded.
8. Before more tests are made, the testing machine should be calibrated.

1. Further investigation of the above observations should be made and steps should be taken to improve it if necessary, with a view to the following:
 - a. Larger dimensions and smaller α (1/2 inch).
 - b. Increased α (in inches) at the corner line and in the tail between two adjacent corner holes at the edge and the corner line.
 - c. To determine more completely the nature of the distribution.
2. Further work should be conducted to compare the operation of the apparatus when the hydraulic shock was used and when the loading was done directly upon the column.
3. Column tests should be run (as "a" edge supports) to determine whether this support is obtained at the "a" edge.
4. The test pieces will be more accurately cut if sandblasted in place before the edges are machined instead of after.
5. Riehm's theory should be utilized to predict the critical load for various experimental work.
6. More data should be obtained in the region of low critical loads.
7. A thin gage with a longer travel is necessary to measure the growth of wrinkles on the plate in loading.
8. Before more tests are made, the loading machine should be calibrated.

VII. APPENDIX

XXXXXXXXXX .119

A. SUPPLEMENTARY INTRODUCTION

1. S-9 Project

Presented herein is a pertinent excerpt of Project S-9 of the Hull Structures Committee of the Society of Naval Architects and Marine Engineers.

Proposal

Project S-9, Buckling Strength of Hull Structures

9 April 1953

"It is the opinion of the S-9 panel that progress in the subject of the buckling strength of hull structures may best be accomplished by a combination of library and experimental research preferably carried out together to avoid duplication and, at the same time, to avoid undue delay. The two proposals presented at the 5 December meeting of the Hull Structure Committee possessed this balance. Since the funds made available do not permit carrying out the dual program proposed, a more modest one based on the same considerations is submitted at this time.

The desired area of study concerns the behavior of elemental flat plates under pure compressive loading. Even for such geometrically simple elements and loadings there is almost no known experimental verification of theory in the range characteristic of transversely framed ship proportions. Witness to this fact is borne out by the extensive use made of Montgomerie's formulations presented before the Society of Naval Architects of Japan in 1934, which nevertheless do not approximate ship conditions in that the short unloaded edges of the plates were unsupported. Furthermore, in this range any data distinguishing between buckling and ultimate loads is almost non-existent.

1. 2-2-1954

Presented herein is a preliminary survey of the subject of the

Structure Committee of the Society of Naval Architects and Marine Engineers.

History

Project 2-2, Building Committee of the Society of Naval Architects and Marine Engineers

1. 2-2-1954

It is the opinion of the 2-2 group that progress in the subject of the building strength of hull structures may not be accomplished by a combination of theory and experimental research merely carried out together to avoid duplication only, at the same time, to avoid waste of delay. The two proposals presented at the 2-2 meeting resulted in the Hull Structure Committee presenting their own proposal. Since the latter was available to the group carrying out the hull structure research, a more robust one based on the new considerations is submitted at this time. The detailed work of study committee the Institute of Naval Architects

plans when the committee is working, even the most comprehensive study of elements and loads that it should be able to handle. The Institute of theory in the range of structural analysis of ship properties. It seems to this that it is better to get the results of the committee's research and to present them to the committee. The committee of Japan in 1951, after consideration of the ship committee in that the ship committee of the Institute of Naval Architects and Marine Engineers, in their report and the Hull Structure Committee, building and structure committee.

The concrete proposal here made is to obtain experimental data for flat plates simply supported on all four edges and subsequently for loaded edges elastically supported with unloaded edges simply supported for side ratios (a/b) of .33, .50, .75 and width-thickness ratios (b/t) of 40, 70 and 100. Elastic edge restraint coefficients of .25 and .50 per page 436 of Bleich's 'Buckling Strength of Metal Structures,' are contemplated for elastic cases.

Following a thorough literature search of this restricted area of the buckling field, such tests might readily be performed on plates 1/8" thick by 3 ft. wide (about 1/4 full size)."

/s/ J. Harvey Evans
Chairman
Panel for Project 8-9

The committee proposed that there be no further action taken for

that plates simply represent an old idea and should be dropped.

Loaded edges electrically connected with the ground plane, as shown

for the plates (a) (b) (c) (d) (e) (f) (g) (h) (i) (j) (k) (l) (m) (n) (o) (p) (q) (r) (s) (t) (u) (v) (w) (x) (y) (z) (aa) (ab) (ac) (ad) (ae) (af) (ag) (ah) (ai) (aj) (ak) (al) (am) (an) (ao) (ap) (aq) (ar) (as) (at) (au) (av) (aw) (ax) (ay) (az) (ba) (bb) (bc) (bd) (be) (bf) (bg) (bh) (bi) (bj) (bk) (bl) (bm) (bn) (bo) (bp) (bq) (br) (bs) (bt) (bu) (bv) (bw) (bx) (by) (bz) (ca) (cb) (cc) (cd) (ce) (cf) (cg) (ch) (ci) (cj) (ck) (cl) (cm) (cn) (co) (cp) (cq) (cr) (cs) (ct) (cu) (cv) (cw) (cx) (cy) (cz) (da) (db) (dc) (dd) (de) (df) (dg) (dh) (di) (dj) (dk) (dl) (dm) (dn) (do) (dp) (dq) (dr) (ds) (dt) (du) (dv) (dw) (dx) (dy) (dz) (ea) (eb) (ec) (ed) (ee) (ef) (eg) (eh) (ei) (ej) (ek) (el) (em) (en) (eo) (ep) (eq) (er) (es) (et) (eu) (ev) (ew) (ex) (ey) (ez) (fa) (fb) (fc) (fd) (fe) (ff) (fg) (fh) (fi) (fj) (fk) (fl) (fm) (fn) (fo) (fp) (fq) (fr) (fs) (ft) (fu) (fv) (fw) (fx) (fy) (fz) (ga) (gb) (gc) (gd) (ge) (gf) (gg) (gh) (gi) (gj) (gk) (gl) (gm) (gn) (go) (gp) (gq) (gr) (gs) (gt) 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Following a lengthy discussion, the committee decided to

the building itself, and some other things as follows:

1/8" thick by 1/2" wide (approx. 1/2" high).

(a) 1. Heavy metal

Construction

Pages: 100 of 100 (1-10)

2. Buckling Theory

The fundamental general equation for a thin flat plate under the action of forces in its middle plane, when the deflection w is small compared to the thickness t , has been developed by St. Venant from a strain energy analysis approach.

$$\frac{EI}{1-\nu^2} \left(\frac{\partial^4 w}{\partial x^4} + 2 \frac{\partial^4 w}{\partial x^2 \partial y^2} + \frac{\partial^4 w}{\partial y^4} \right) + t \left(\sigma_x \frac{\partial^2 w}{\partial x^2} + \sigma_y \frac{\partial^2 w}{\partial y^2} + 2 \tau_{xy} \frac{\partial^2 w}{\partial x \partial y} \right) = 0 \quad (1)$$

where σ_x and σ_y are the normal stresses in the x and y directions and τ_{xy} is the shear stress. The moment of inertia of a unit strip of plating is $I = \frac{t^3}{12}$, E is Young's modulus, and ν is Poisson's ratio.

When $\sigma_y, \tau_{xy} = 0$, the equation simplifies to the form,

$$\frac{EI}{1-\nu^2} \left(\frac{\partial^4 w}{\partial x^4} + 2 \frac{\partial^4 w}{\partial x^2 \partial y^2} + \frac{\partial^4 w}{\partial y^4} \right) + \sigma_x t \frac{\partial^2 w}{\partial x^2} = 0 \quad (2)$$

Eleich [8] has suggested an empirical modification of equation (2) for all cases, even those where the critical stress may exclude the proportional limit.

$$D \left(\tau \frac{\partial^4 w}{\partial x^4} + 2 \sqrt{\tau} \frac{\partial^4 w}{\partial x^2 \partial y^2} + \frac{\partial^4 w}{\partial y^4} \right) + \sigma_x t \frac{\partial^2 w}{\partial x^2} = 0 \quad (3)$$

2. Bending Theory

The fundamental general equation for a thin plate under the action of forces in the middle plane, when the deflection w is small compared to the thickness t , has been developed by Dr. Timoshenko's strain energy method approach.

$$0 = \frac{EI}{1-\nu^2} \left(\frac{\partial^4 w}{\partial x^4} + \frac{\partial^4 w}{\partial y^4} + 2 \frac{\partial^4 w}{\partial x^2 \partial y^2} \right) + \frac{1}{2} \left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} \right) + \frac{1}{2} \frac{\partial^2 w}{\partial x^2} + \frac{1}{2} \frac{\partial^2 w}{\partial y^2}$$

where ν and $\frac{EI}{1-\nu^2}$ are the normal stresses in the x and y directions and $\frac{1}{2} \left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} \right)$ is the shear stress. The moment of inertia of a unit strip of plate is $I = \frac{t^3}{12}$, E is Young's modulus, and ν is Poisson's ratio.

When $\nu = 0$, the equation simplifies to the form

$$0 = \frac{EI}{1-\nu^2} \left(\frac{\partial^4 w}{\partial x^4} + \frac{\partial^4 w}{\partial y^4} + 2 \frac{\partial^4 w}{\partial x^2 \partial y^2} \right) + \frac{1}{2} \left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} \right)$$

Equation [3] has appeared in equivalent modifications in various forms for all cases, even those where the middle plane is not in the middle plane.

$$0 = \frac{EI}{1-\nu^2} \left(\frac{\partial^4 w}{\partial x^4} + \frac{\partial^4 w}{\partial y^4} + 2 \frac{\partial^4 w}{\partial x^2 \partial y^2} \right) + \frac{1}{2} \left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} \right)$$

For wide plates, however, he recommends the use of a simplified equation by Ros and Michinger,

$$D \nabla^4 \left(\frac{\partial^4 w}{\partial x^4} + 2 \frac{\partial^4 w}{\partial x^2 \partial y^2} + \frac{\partial^4 w}{\partial y^4} \right) + \sigma_x t \frac{\partial^2 w}{\partial x^2} = 0 \quad (4)$$

since it presents an easier solution, and since the difference between the results of equations (3) and (4) is not very great for such plates.

The general solution of equation (4) is

$$w = \sin \frac{\pi y}{b} \left(c_1 \cos \alpha_1 \frac{x}{b} + c_2 \cos \alpha_2 \frac{x}{b} \right) \quad (5)$$

where
$$\alpha_{1,2} = \frac{\pi}{2} (\sqrt{K} \pm \sqrt{K-4})$$

and it develops that when the boundary conditions of simple support are satisfied, the following characteristic equation is obtained:

$$\alpha_1 \tan \frac{\alpha_1}{2} - \alpha_2 \tan \frac{\alpha_2}{2} + \alpha \int (\alpha_1^2 - \alpha_2^2) = 0 \quad (6)$$

where \int is the coefficient of edge restraint.

This equation yields characteristic values of σ_x at which the plate changes from one configuration to another, the lowest value being the buckling stress, σ_{cr} .

$$\sigma_{cr} = \frac{\pi^2 E T}{12(1-\nu^2)} \left(\frac{t}{b} \right)^2 K \quad (7)$$

$$\text{or} \quad \sigma_{cr} = \frac{\pi^2 E T}{12(1-\nu^2)} \left(\frac{t}{a} \right)^2 \bar{K} \quad (8)$$

where
$$\bar{K} = \alpha^2 K.$$

For this paper, however, the relationship between the two is not

equation of the two is not

$$(1) \quad D = \left(\frac{9\pi}{4} + \frac{9\pi}{4} \right) + \frac{9\pi}{4} = 0$$

since it represents an entire solution, and since the difference between

the results of equations (1) and (2) is not very great (see Table 1),

the general solution of equation (1) is

$$(2) \quad u = \sin \left(\frac{\pi}{2} \right) \left(\cos \frac{\pi}{2} + \cos \frac{\pi}{2} \right)$$

$$\text{where } \frac{\pi}{2} = \frac{\pi}{2} \pm \frac{\pi}{2}$$

and it follows that the boundary conditions of single points are

satisfied, the following characteristic equation is obtained

$$(3) \quad 0 = \left(\frac{\pi}{2} - \frac{\pi}{2} \right) \left(\frac{\pi}{2} + \frac{\pi}{2} \right) + \frac{\pi}{2} = 0$$

where $\frac{\pi}{2}$ is the coefficient of the equation

This equation yields characteristic values of $\frac{\pi}{2}$ and the other

changes from one solution to another, the characteristic values of

including terms of order

$$(4) \quad \frac{\pi}{2} = \frac{\pi}{2} + \frac{\pi}{2}$$

$$\frac{\pi}{2} = \frac{\pi}{2} + \frac{\pi}{2}$$

or

$$\frac{\pi}{2} = \frac{\pi}{2}$$

where

Bleich presents a table of K values for various combinations of end \int [Ref. 8, p. 436]. For plates simply supported

Solution of equation (3) for conditions of simple support at all four edges gives the result

$$\sigma_{cr} = \frac{\pi^2 E \sqrt{T}}{12(1-\nu^2)} \left(\frac{t}{b}\right)^2 \left(\frac{\alpha}{n^4 \sqrt{T}} + \frac{n^4 \sqrt{T}}{\alpha}\right)^2 \quad (9)$$

where n is the number of half-waves in the buckled shape.

3. Determination of Buckling Load

The theoretical buckling load is the load at which the plate suddenly departs from its plane condition and assumes a buckled shape with two-dimensional curvature. This load can be calculated by applying the "least work" approach introduced by Kirchhoff and applied to plates by Bryan. In practice this phenomenon may not occur abruptly due either to initial "unplaneness" of the plate, or to the fact that the yield point is reached in the fibers of the plate before buckling occurs. The buckling load as obtained in practice must be a rather fictitious value found by some less direct means. Methods available are the "top-of-the-knee" method, the "stress-reversal" method, Vasta's method [19], Yoshiki's method 60, and Southwell's or Donnell's method [48], [18]. The top-of-the-knee method depends upon the rate of change of the lateral deflection with increasing load. This deflection may be measured directly, or the bending moment in the plate as determined by the difference of the strains on opposite sides of the plate may be used as an indicative value. The strain reversal method defines the buckling load as that at which the slope of the strain-load curve for either side

Table presents a table of \bar{F} values for various combinations of

and [Ref. 3, p. 136]. For plates singly supported

solution of equation (3) for conditions of single support at

four edges gives the result

$$\omega = \frac{\pi^2 E \sqrt{T}}{12(1-\nu^2)} \left(\frac{1}{b} \right)^2 \left(\frac{1}{\sqrt{T}} \right)^2 + \frac{1}{\alpha} \left(\frac{1}{\sqrt{T}} \right)^2 \quad (9)$$

where n is the number of half-waves in the loaded length.

3. Determination of Buckling Load

The theoretical buckling load is the load at which the plate suddenly departs from its plane condition and assumes a buckled shape with two-dimensional curvature. This load can be calculated by applying the "least work" approach introduced by Timoshenko and applied to plates by Meyer. In practice this procedure may not be completely due either to initial "imperfections" of the plate, or to the fact that the yield point is reached in the fibers of the plate before buckling occurs. The buckling load as obtained in paragraph 2 will be a theoretical value based on some ideal assumptions. Timoshenko and Meyer the "top-of-the-knee" method, the "bottom-of-the-knee" method [19], Timoshenko's method [20], and the method of the lateral deflection at the load [21]. The top-of-the-knee method depends upon the rate of change of the lateral deflection at the load. The bottom-of-the-knee method depends directly on the bending moment in the plate as indicated by the difference of the strains on opposite sides of the plate at the load as an indicative value. The lateral deflection method utilizes the buckling load as that at which the slope of the lateral deflection curve becomes

of the plate reverses direction. Vasta's method is based upon the shortening of the plate in the direction of the load, and could be applied with difficulty in this investigation since it is based upon a "constant-deflection" application of the load. Yoshiki attempted to accentuate the change of slope in the load-deflection curve used in the "top-of-the-knee" method by plotting deflection-squared versus the load.

Southwell's method is based upon the bending of a column which has some initial unfairness. Starting with the basic differential equation, the following expression can be arrived at:

$$\frac{d}{P} P_{cr} = d \quad d_0 \quad (10)$$

If a plot is made of $\frac{d}{P}$ vs. d , the slope of the line is the inverse of the critical load, and the intercept on the d -axis is the initial deflection d_0 .

Donnell has devised a variation on Southwell's method which has some advantages. If P is plotted against $\frac{P}{d}$, a line is obtained whose equation is:

$$P_{cr} = P \quad d_0 \quad \frac{P}{d} \quad (11)$$

The intercept on the P -axis is the buckling load, and the slope is the initial unfairness.

of the plate between different. Van der Waals' method is based upon the
 assumption of the plate in the direction of the lead, and could be
 applied with difficulty in this investigation since it is based upon
 a "constant-temperature" assumption of the lead. Further attempts
 to account for the change of slope in the lead-temperature curve used
 in the "top-of-the-lead" method by plotting differential-temperature
 the lead.

Van der Waals' method is based upon the plotting of a curve which has
 some initial maximum. Starting with the leads differential-temperature
 the following expression can be written as:

$$(10) \quad \frac{d}{dt} \ln \frac{d}{dt} = \frac{d}{dt} \ln \frac{d}{dt}$$

If a plot is made of $\frac{d}{dt} \ln \frac{d}{dt}$ vs. d , the slope of the line in the interval of
 the original lead, and the intercept on the d -axis is the initial differ-
 ence d_0 .

Van der Waals has derived a variation on Van der Waals' method which has been
 suggested. If $\frac{d}{dt} \ln \frac{d}{dt}$ is plotted against $\frac{d}{dt}$, a line is obtained whose
 equation is:

$$(11) \quad \frac{d}{dt} \ln \frac{d}{dt} = \frac{d}{dt} \ln \frac{d}{dt}$$

The intercept on the d -axis is the initial lead, and the slope is the
 initial maximum.

B. DETAILS OF PROCEDURE

1. Design of the Test Apparatus

a) General

The survey of the pertinent literature indicated that Polyclone [40] and Capozzoli [12] had tested plates of high aspect ratios at Massachusetts Institute of Technology. Equipment was designed and built to provide simple support of the unloaded edges. This equipment was made available to this project if its use proved feasible. The total length of support for each edge was 34"; hence this limited the total length of "a"-edges of each group of plates to be tested if these supports were to be used. A chart was made of the ratios a/b , a/t and t of the plate specimens using values of t for standard plate sizes and limiting the thickness to $5/16$ ", the maximum capacity of the supports.

The maximum capacity of the materials laboratory hydraulic testing machines was 300,000 pounds. This placed an upper limit on the size of plates which could be tested.

With these two criteria, i.e., the total length of "a"-edges and the testing machine capacity, the plate sizes were selected and are presented in Table I.

b) B-Edges

Since the longest selected plate was 56.75" in length, the testing jig must be about 5 feet in length. The upper head of the testing machine presented an annular bearing surface 18" O.D. by 11" I.D. The lower head was a 2 foot square. Expected load analyses of the proposed plate sizes indicated that size 43.75" x 10.19" x $7/32$ "

1. Index of the Test Apparatus

a) General

The survey of the apparatus is shown in Figure 1. The apparatus is designed to measure the rate of reaction between a gas and a solid. The reaction is carried out in a glass vessel of known volume, which is equipped with a stirrer and a gas inlet. The gas is introduced through a tube which is connected to a gas cylinder. The solid is introduced through a separate tube. The reaction is initiated by the introduction of the gas. The rate of reaction is determined by measuring the volume of gas which is consumed during a given time interval. The volume of gas consumed is measured by the displacement of a liquid in a graduated cylinder. The rate of reaction is expressed in terms of the volume of gas consumed per unit time.

The reaction is carried out at a constant temperature. The temperature is controlled by a water bath. The water bath is equipped with a thermometer and a heater. The temperature of the water bath is maintained at a constant value by the use of a thermostat. The rate of reaction is determined by measuring the volume of gas which is consumed during a given time interval. The volume of gas consumed is measured by the displacement of a liquid in a graduated cylinder. The rate of reaction is expressed in terms of the volume of gas consumed per unit time.

b) Details

The apparatus is shown in Figure 1. The apparatus is designed to measure the rate of reaction between a gas and a solid. The reaction is carried out in a glass vessel of known volume, which is equipped with a stirrer and a gas inlet. The gas is introduced through a tube which is connected to a gas cylinder. The solid is introduced through a separate tube. The reaction is initiated by the introduction of the gas. The rate of reaction is determined by measuring the volume of gas which is consumed during a given time interval. The volume of gas consumed is measured by the displacement of a liquid in a graduated cylinder. The rate of reaction is expressed in terms of the volume of gas consumed per unit time.

imposed the severest condition on the jig both strength-wise and from the standpoint of distributing the edge loading.

Preliminary calculations indicated that allowing a stress variation of 5% along the loaded edge an I-beam of approximately 12 feet in depth would be required to bridge the gap from the head of the testing machine to 43.75" length of plate edge. This was in line with the experience of the David Taylor Model Basin where constant displacement heads of the same order of magnitude were found necessary.

It was felt that a more practical solution would involve the use of hydraulic means to distribute the load. Accordingly it was found that commercial 20-ton hydraulic jacks could be fitted in the testing jig, seven on each edge connected to a common manifold, which when backed by an I-beam of approximately 18" depth should provide a solution to the problem. These jacks could be placed along the I-beam (See Fig. 27) with different intervals to suit the particular plate size. It was found that these commercial jacks (See Fig. 31) could normally be expected to withstand a 10% overload. Considering this, seven 20-ton jacks would equal the rated capacity of the testing machine, i.e., 300,000 pounds.

There still remained the problem of converting the load from each jack to a more uniform load on the plate edges and still maintaining this edge as simply supported. Frankland [19] merely butted the square edge of the plate against the flat loading lead relying on friction to prevent lateral motion; Yoshiki [60] used the same arrangement except that he rounded the edges of the plate to minimize the rotational restraint.

The present investigation was carried out on the basis of the results of the previous work on the strength of the edges of plates. The results of the previous work are given in the Appendix. The present work is devoted to the study of the strength of the edges of plates under the action of a uniform load. The results of the present work are given in the Appendix. The present work is devoted to the study of the strength of the edges of plates under the action of a uniform load. The results of the present work are given in the Appendix.

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Since both of these methods necessitated very careful machining of the plate edges, it was felt that the same result could be accomplished by using the milled or slotted cylinders which would fit over the edge of its plate and bear on a loading bar which could also be used to bridge the gap between the jacks. (See Fig. 27) The cylinders, or loading segments should be restricted in length to minimize torsional restraint on the loaded plate edge. Both the segments and the bar could then be hardened to resist deformation under the high loading at the point of contact. The loading bar was ground flat on one surface and flat with a shallow groove in the other surface. It was believed this groove might be necessary to restrict lateral movement of the plate.

c) "A"-Edges

In order to avoid transmittal of load to the "a"-edge supports, these supports should be completely independent and mounted free from the "b"-edge loading arrangement. The "a"-edge support should prevent lateral motion of the edge of the plate while permitting both rotation and translation in the plane of the plate.

It was found that the "a"-edge supports designed by Polychrom [40] and modified by Capozzoli [12] permitted freedom of rotation of the plate edge for about 20° on either side of the plate axis if the ball bearing races were permitted to slide on the channel sides (See Fig. 29). The ball bearing support allows translation in the plane of the plate and can be adjusted to the thickness of the plate by the use of spacers between the race support and the channel, with the final adjustment of the desired pressure being accomplished with the thumb screws. The channels are held in place by an arrangement of

Since both of these methods necessitated very careful handling

of the plate edges, it was felt that the more reliable method of
controlling by using the miller or similar equipment which would fit
over the edge of the plate and bear on a loading bar which could also
be used to bridge the gap between the plates. (See Fig. 27) The
cylindrical, or loading segments would be restricted in length to
minimize torsional stresses on the loaded plate edges. With the
segments and the bar could then be maintained in contact deformation
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(c) "A"-edges

In order to avoid transmission of load to the "A"-edge supports,
these supports should be completely independent and mounted free
from the "B"-edge loading arrangement. The "A"-edge supports should
prevent lateral motion of the edge of the plate while permitting
both rotation and translation in the plane of the plate.
It was found that the "A"-edge supports could be designed by
[40] and modified by [41] [42] [43] [44] [45] [46] [47] [48] [49] [50]
the plate edge for about 20" on either side of the plate ends to the
ball bearing were permitted to slide on the channel sides (See
Fig. 50). The ball bearing supports allow translation in the plane of
the plate and can be adjusted to the thickness of the plate by the
use of spacers between the rear support and the channel. With the
final adjustment of the desired pressure being applied, the plate
translates. The channels are held in place by the

rods and turnbuckles connected to angle iron braces rigidly attached to the frame of the testing machine. (See Fig. 33)

The two "a"-edges are connected to each other by an angle on either side of the plate to prevent the support from slipping off the plate edge. These angles both have one edge planed to serve as a base for the sliding dial gage with which actual deflection measurements (d') can be read.

d) Hydraulic Jacks

The I-beams were both skim-machined to provide a flat base for the hydraulic jacks. These jacks are further held in position by two angles on either side which are bolted to the I-beam but hold the jacks only by clamping friction. These angles are slotted to accommodate the hydraulic fittings as the jack positions are changed. The Blackhawk Company, manufacturers of the hydraulic jacks, indicated that reasonably equal pressures could be expected in each jack when several were connected to a common manifold. Some slight variation in delivered force, however, may be expected from varying friction loads in the different jacks and varying back pressures created by the tension in the spring of the piston return mechanism.

Each of the seven jacks along one edge of the plate was connected to a manifold manufactured from 3" diameter cold rolled steel. (See Fig. 30). This manifold also had outlets on which a pump and pressure gage could be mounted. (See Fig. 34).

roads and transmission connected to engine from engine slightly extended

to the front of the testing machine. (See Fig. 11)

The two "a"-edges are connected to each other by an angle on either

sides of the plate to prevent the support from slipping off the plate
edges. These angles both have one edge joined to serve as a base for the
sliding that page with which actual deflection measurements (Fig. 12) can be

read.

(b) Hydraulic Joints

The I-beams were both side-mounted to provide a flat base for the
hydraulic joints. These joints are further held in position by two angles
on either side which are bolted to the I-beam and hold the joints only by
sliding friction. These angles are riveted to accommodate the hydraulic
fittings as the test positions are changed. The hydraulic coupling, however,
features of the hydraulic joints, indicated that reasonably equal pressures
could be expected in each joint when several were connected to a common

manifold. Some slight variation in deflection force, however, may be
expected from varying friction loads in the different joints and varying
back pressures created by the tension in the spring of the piston return
mechanism.

Each of the seven joints along one edge of the plate was connected

to a manifold manufactured from 3" diameter cold rolled steel. (See

Fig. 10). This manifold also had outlets in which a pump was pressure

applied could be mounted. (See Fig. 13).

2. Procedure for Setting Up Equipment

In order to facilitate future use of the equipment a brief description of the method of assembling the test equipment is given. The weight handling equipment consists of a chain hoist and a narrow four wheeled truck which will fit easily between the frame of the testing machine. The steps are as follows:

- a.) With the chain hoist and sling place the upper I-beam on the truck and move into position in the testing machine under the upper head of the machine. A $1/4"$ shim will be found between a spacing ring clamped to the I-beam and the beam itself. This shim should be towards the window. It is convenient to lift the wheels of the truck over the ledge created by the difference in height of the floor level and the lower head, by means of a lever. The wheels are then blocked up to the proper height and the truck moved on to the lower head. Once the equipment is on the lower head it is advisable to raise the lower head slightly, about $1/2"$ to prevent the possibility of locking equipment between the upper and lower heads. Should such a lock become positive it might be necessary to dismantle the testing machine to remove the equipment.
- b.) The upper head is lowered carefully over the 2" stud protruding from the I-beam. The plate washer and nut is secured loosely on the stud. The I-beam may now be lifted clear of the truck and the truck removed. It may be convenient now to lower its I-beam until it barely rests on the lower head. The beam may now be positioned on the head. Scribe marks will be found on the spacing ring and the upper head of the testing machine to facilitate alignment. When the beam is in place the 2" nut should be tightened and the upper head raised about 2 ft. clear of the lower head.

2. Procedure for Setting Up Equipment

In order to facilitate future use of the equipment, the following

steps should be followed in setting up the equipment in general. The

weight handling equipment consists of a chain hoist and a power

hoisted truck which will lift easily between the frames of the building

machine. The steps are as follows:

a.) With the chain hoist and after the power hoist is set up

and move into position in the building machine under the power hoist

the machine. A 1/2" chain will be found between a spacing when raised

to the I-beam and the beam itself. This chain should be removed from

between. It is convenient to lift the wheels of the truck over the ledge

created by the difference in height of the I-beam level and the lower

head, by means of a lever. The wheels are then blocked up to the lower

height and the truck moved on to the lower head. Once the equipment is

on the lower head it is advisable to raise the lower head slightly

1/2" to prevent the possibility of loading equipment between the upper

and lower beams. Should such a load become positive it will be necessary

to dismantle the loading machine to remove the equipment.

b.) The upper head is lowered carefully over the 2" steel beam between the

the I-beam. The plate washer and nut is removed loosely on the head.

The I-beam may now be lifted clear of the truck and the truck removed

It may be convenient to lower the I-beam until it is nearly level on

the lower head. The beam may now be positioned on the lower head.

marks will be found on the spacing and the lower head of the beam.

ing machine to facilitate alignment. This may be done by using the

and should be placed on the upper head when the lower head is

the lower head.

c.) The upper system of jacks, already positioned as desired between the clamping angles may now be lifted as a unit and placed on the truck. It will be found that if care is taken, the jack feet are wide enough to prevent this assembly from tipping. The truck is then moved into position under the upper I-beam and the bolts secured. The upper head and jack system is lifted to a maximum height and the truck removed.

d.) It is usually convenient to leave the lower system of jacks attached to the lower I-beam. This whole assembly then may be lifted on the truck and moved into position on the lower head with only the front wheels on the lower head. The lower head is raised about 1" or 2" and a block is placed under the higher end of the beam. The head is then lowered so that one end of the I-beam now rests on the block. The other end of the beam is then lifted clear of the truck with the chain hoist and the truck removed. The lower head is then raised until the I-beam is nearly supported by it. A 1/4" shim is inserted under the edge of the I-beam nearest the window. It is advisable at this point to position the lower I-beam on the head by lowering the upper head and matching the opposing jacks. Such shims as deemed necessary under the lower head are best inserted at this point. The blocks and chain hoist are then removed and the lower head brought down to about 1" from its lowest position.

e.) The "a"-edge supporting angles with rods attached may then be placed and clamped to the proper height on the H-beam frames of the testing machine. The "a"-edge channels, held together with their supporting angles which are spaced according to the width of the plate specimen, are slid into position and rested on the ends of the lower leading bar. The turnbuckles may then be secured and the "a"-edge supports lined up.

a.) The upper system of jacks, already mentioned as being in position, the slanting angles may now be lifted as a unit and placed on the track. It will be found that if care is taken the track will be lifted through the pressure this assembly from lifting. The track is now in the same position under the upper I-beam and the jacks removed. The upper beam and jacks

system is lifted to a maximum height and the jacks removed. b.) It is usually convenient to leave the lower system of jacks attached to the lower I-beam. This whole assembly then may be lifted on the track and moved into position on the lower beam with only the lower wheels on the lower beam. The lower beam is raised about 1" or 2" and a block is placed under the right end of the beam. The beam is then lowered so that one end of the I-beam now rests on the block. The other end of the beam is then lifted about 1" or 2" with the chain hoist and the lower removed. The lower beam is then raised until the lower beam is nearly supported by 1 1/2" which is inserted under the edge of the I-beam near the other end. It is advisable at this point to position the lower I-beam on the track by lowering the upper beam and moving it as required. Jacks. Such things as desired necessary under the lower beam are now inserted at this point. The blocks and chain hoist are then removed and the lower beam brought down to about 1" from the lower beam and lower.

c.) The "A" edge supporting system which was attached and which is shown and slanted to the proper height on the I-beam frame of the machine. The "A" edge assembly, built together with the supporting angles which are placed according to the width of the lower beam are slid into position and rested on the ends of the I-beam frame. The front rollers are then be secured and the "A" edge assembly lifted up.

f.) After initial deflection of the plate readings are taken, the test plate is placed in position between its "a"-edge channels and rested on the lower loading bar. The ball-bearing races are inserted to hold the plate in place. The shims for the loading segments, if used, are held in position along the top edge either with C-clamps or a segment placed at each end, or both. The gasket material may be placed along the edge and the remaining segments positioned on the top edge of the plate over the gasket and shims. The method of placing the segments along the bottom edge of the plate depends upon the type of gasket material used. The thumbscrews on the "a"-edge channels are tightened so that the plate may be suspended from the "a"-edge supports. The lower head of the testing machine is then lowered slightly. If solder gasket material is used, the head is lowered about 1/2". The segments may then be slid into position from either end of the plate. The solder may also be run in from the end of the plate between the segments and the plate edge. The shims are then inserted between the segment and the side of the plate. If a flat gasket such as the neoprene strip is used the segments must be rolled in from the side of the plate. Careful spacing of the distance between the plate edge and the loading bar is necessary to accomplish this successfully. The lower head is then raised until the plate is supported. Both upper and lower head and the "a"-edge supports are then positioned so that approximately equal plate overhang remains above and below each "a"-edge support. The plate is now ready to load.

g.) The strain gage hook up may now be completed and zero readings taken. The pressure gage and hand pump may be connected to the manifolds if desired. A slight load should be placed on the plate, probably not exceeding 1000 pounds. The loaded edges of the plate may be forced into

[illegible]

a straight line as the segments tend to seek the lowest part of the groove in both loading bars. It is useful to apply some grease to the loading bar grooves to facilitate this operation and subsequent sliding when plate deflections are large. The straightness of the edge may be checked by eye or with a straight edge. Zero or near-zero deflection readings may be taken with the dial gage at desired locations along the horizontal center line of the plate.

h.) The application of the load should be gradual at first until all jacks have time to equalize their internal pressure. There should be about 2" of each jack ram protruding, more perhaps when higher loads are reached. The amount will depend on the degree of leakage in the system. A stress of about 1000 psi is needed to deform the solder gasket if this type is used. The load corresponding to this stress should be placed on the plate and allowed to remain until the rate of decrease of its load is nearly zero. If it is desired to obtain test points below this loading care must be taken not to unload the plate entirely if straightening of the "b"-edge was required. The test is now ready to proceed.

i.) Disassembly of the equipment generally follows the reverse of the method described above.

3. Explanation of Test Description

In order to evaluate the affect of the various components of the test apparatus, tests under different conditions were run and described cryptically in the data sheets and on the graphic results. (Figs. 1 to 20).

a straight line as the sequence from to each the lower part of the groove in both loading bars. It is useful to apply some pressure to the loading bar grooves to facilitate this operation and subsequent sliding when plate deflections are large. The straightness of the edge may be checked by eye or with a straight edge. Care or care-free deflection readings may be taken with the dial gage at desired locations along the horizontal center line of the plate.

1. The application of the load should be gradual at first until all jacks have time to equalize their internal pressure. There should be about 2" of each jack rod protruding, more protrusion when higher loads are reached. The amount will depend on the degree of leakage in the system. A stress of about 1000 psi is needed to defeat the solution. Check if this type is used. The load corresponding to this stress should be placed on the plate and allowed to remain until the rate of decrease of the load is nearly zero. If it is desired to obtain load points below this loading rate may be taken up to release the plate entirely if unloading of the "B" edge was required. The test is now ready to proceed.

1. Disassembly of the equipment generally follows the reverse of the method described above.

3. Explanation of Test Description

In order to evaluate the effect of the various components in the test apparatus, tests were conducted with and without the cylindrical in the test apparatus and on the rigid surface. (Type 1)

a.) Load Application - Machine or Pump

It was intended that each set of hydraulic jacks (top and bottom) would be connected to a common manifold with the jacks partially extended. The testing machine would then be used to apply the load to the jack system. In an attempt to evaluate effects of jack friction a hydraulic hand pump was connected to the top group of jacks and the load was applied in this manner. It was found also that the quieter operation of the hand pump was more conducive to efficient test procedure, hence this method was generally used on subsequent tests.

b.) Jacks - No Jacks

One set of tests was run without the hydraulic jacks in order to ascertain their effect. When the jacks were removed the two loading I-beams were shimmed so as to be as nearly parallel as practicable.

c.) Bar

The hardened loading bar designed for the apparatus is designated by the thickness ($3/4"$) and whether the flat (F) or grooved (G) side of the bar bore on the segments. (See detail Fig. 27). Since the loading pressures on this particular size of plate are comparatively low, cold rolled steel bars $1\ 1/4"$ wide and thicknesses $1/16"$, $1/4"$, $5/16"$ and $3/8"$ were substituted in various tests in an effort to shed light on the effect of the stiffness of the bar on the test results.

d.) Gasket

In an attempt to eliminate local unevennesses in the edge of the test plate various sizes and types of gasket materials were placed along the edge of the plate under the bearing segments. Where a plastic gasket material was used such as the solder, the gasket was first set by running up the load to approximately 20,000 pounds and allowing the gasket material

2. Load Application - Machine or Prop

It was intended that each set of hydraulic jacks (top and bottom) would be connected to a common manifold with the jacks partially extended. The testing machine would then be used to apply the load to the jack system. In an attempt to eliminate effects of jack friction a hydraulic hand pump was connected to the top group of jacks and the load was applied in this manner. It was found also that the pressure operation of the hand pump was more conducive to efficient test procedure, hence this method was generally used on subsequent tests.

3. Jacks - No Load

One set of jacks was run without the hydraulic jacks in order to ascertain their effect. When the jacks were retracted the bar loading increased as shown in Fig. 2. It was found that the jacks were not perfectly aligned as indicated.

4. Bar

The instrument loading bar designed for the apparatus is described by the dimensions (Fig. 3) and whether the load (Y) or pressure (Z) was applied the bar bore on the segments. (See detail Fig. 3). When the loading pressure on this particular side of plate was approximately 1000 psi, the rolled steel bars 1 1/2" wide and thickness 1/8", 1/4", 3/8" and 1/2" were substituted in various tests in an effort to find the effect of the alignment of the bar on the test results.

5. Plates

In an attempt to eliminate local stresses in the edge of the plate various sizes and types of gasket materials were placed along the edge of the plate under the bearing segments. When a plastic material was used such as the rubber, the gasket was found to be effective up the load to approximately 10,000 pounds and after that the gasket failed.

to flow plastically for several minutes until the rate of drop in the load was approximately equal to that of normal leakage in the hydraulic system.

The neoprene gasket was cut from a sheet $1/16"$ thick to a width equal to the approximate thickness of the test plate. Two diameters of solder gaskets were used, $1/16"$ and $3/32"$. The $1/16"$ solder was used as a double strip side by side, whereas only a single strip of the $3/32"$ diameter solder was used. During two tests where no segments were used, a strip of lead house sheathing about 1" wide and $1/16"$ thick was placed between the loading bar and the edge of the plate.

e.) Segments - No Segments

Since most of the test results indicated the presence of fairly high moments in the plate from the beginning of the tests, it was decided advisable to determine whether or not the bearing segments influenced this phenomenon. Accordingly during several tests these segments were removed and the plate was butted up against a sheet lead gasket on the loading bar.

f.) Shims - No Shims

The segments were made with the slot a minimum of $1/32"$ wider than the plate. In order to reduce the possibility of eccentric loading and to check the effect of this clearance on the observed moments in the test plate shim stock was inserted to reduce this clearance. On the tests where shims are indicated, shim stock of $.015"$ and $.002"$ were placed between both sides of the segment and the plate making a total addition of shim stock $.034"$ on each "b"-edge. The maximum estimated clearance between the plate and the segments after the introduction of these shims is $.003"$.

to flow practically for several minutes until the rate of drop in the load was approximately equal to that of normal leakage in the hydraulic system.

The mercury gasket was cut from a sheet $1/16"$ thick to a width equal to the approximate thickness of the test plate. Two diameters of solder gaskets were used, $1/16"$ and $3/32"$. The $1/16"$ solder was used as a double strip wide by side, whereas only a single strip of the $3/32"$ diameter solder was used. During two tests where no segments were used, a strip of lead having thickness about $1/16"$ wide and $1/16"$ thick was placed between the loading bar and the edge of the plate.

e.) Segments - No Shims

Since most of the test results indicated the presence of fairly high moments in the plate from the beginning of the tests, it was decided advisable to determine whether or not the bearing segments influenced this phenomenon. Accordingly during several tests these segments were removed and the plate was pulled up against a sheet lead gasket on the loading bar.

f.) Shims - No Shims

The segments were made with the slot a minimum of $1/16"$ wider than the plate. In order to reduce the possibility of eccentric loading and to check the effect of this clearance on the observed moments in the test plate this stock was inserted to reduce this clearance. In the tests where shims are indicated, this stock of .015" and .005" were placed between both sides of the segment and the plate making a even thickness of shim stock .015" on each "V"-edge. The maximum clearance observed between the plate and the segments after the introduction of these shims is .005".

g.) Load

The load was measured on the most sensitive gage of the testing machine that would record the load. Three gages are available of ranges 0-30,000 pounds, 0-150,000 pounds, 0-300,000 pounds. All gages have adjustable zero readings so that the weight of the apparatus in the machine is compensated except for the upper loading bar and segments.

h.) P_i - Internal Hydraulic Pressure of Top System of Jacks

In order to provide a check on the total load recorded in the testing machine and to aid in determining the force system on the loading bar should this be necessary, a pressure gage 0-1000 pounds was mounted directly on the upper manifold of the top hydraulic jack system and the pressures recorded.

i.) Strain Gage Readings

These readings are direct readings of the strain gage indicator. The index number did not change during any given test and to save space this number is recorded only under the zero reading. The zero reading was taken after the gasket had been set but with the blocks used to minimize the curvature of the test plate in the "b"-edge direction, still in place. Time did not permit complete cycling of the gages on each run but final zero readings were taken periodically to check the instrumentation. The dummy gage was mounted on a plate of the same thickness and same material as the test plate. The leads to the strain gage indicator were about the same length as those from the test plate. The dummy gage was located as close as practicable to the test plate.

j.) Deflections

Initial deflections in the "a"-edge direction were recorded on

~~subjected him to some criticism from his no longer any kind of~~

7. Machines are being used to record the following data:

7. With the above said, the proposed change is correct. - 17 (11)

[illegible]

SECRET

[illegible]

3.11.3.40.50 102

1955 年 12 月 25 日 星期一 晴

Plates 2, 3, and 4 at 6" intervals from the center line and at the center. Deflections at the center line in the "b"-edge direction were recorded at each gage location on Plates No. 1 and No. 2 except near the "a"-edges on Plate No. 1 where wiring interfered. Here the deflection noted was between the two end gages as noted. Deflections on Plate Nos. 3 and 4 were recorded at the same location as the initial readings. It will be noted that in certain cases the deflections exceeded the maximum travel of one-half inch on the dial gage.

k.) Plate Orientation

In Figs. 1 to 20 the plate orientation is indicated by the number of the strain gage in each corner. This plate was reversed during later tests along a diagonal as a check on effect of unevenness in the edge of the plate.

l.) Computed Strain

The computed average strain based on a load of 10,000 pounds and the area of the test plate ($b' \times t$) assuming a value of $E = 28,300$ kips/inch² is shown as a dashed horizontal line

$$\sigma_{av} = \frac{10,000}{56.75 \times .15625 \times 28.3 \times 10^6} = 40.3 \mu \text{ in/in}$$

Since the accuracy of the individual strains plotted is $5 \mu \text{ in/in}$ only values of the individual strains above 45.3 or below 35.3 should be considered as different from average values.

h. Data on Test Plates

a.) Length - $L = 13.3125"$

b.) Width - $b' = 56.75"$

c.) Thickness - This dimension varied slightly among the four test plates. Measurements were taken along the edge with a micrometer. The

Plates 2, 3, and 4 at 0° intervals from the center line and at the center. Deflections at the center line in the 0°-edge direction were recorded at each gage location on Plates No. 1 and No. 2 except near the 0°-edges on Plate No. 1 where wing deflections were the deflection noted was between the two end gages as noted. Deflections on Plate No. 3 and 4 were recorded at the same location as the initial readings. It will be noted that in certain cases the deflection exceeded the maximum travel of one-half inch at the first gage.

(c) Plate Orientation

In Figs. 1 to 10 the plate orientation is indicated by the number of the strain gage in each corner. This plate was reversed during later tests along a diagonal as a check on effect of reverseness in the edge of the plate.

(d) Computed Results

The computed average strains shown on a load of 30,000 pounds and the area of the test plate (b' x b) computed a value of 18,750 in²/in² is shown as a dashed horizontal line.

$$\sigma_{av} = \frac{30,000 \times 18.75}{18.75 \times 10^6} = 0.001 \text{ in/in}$$

Since the accuracy of the individual strain gages is 0.0001 in/in only values of the individual strain above 0.001 or below 0.001 in/in be considered as different from average value.

(e) Data on Test Plates

- a.) Length - L = 18.3125"
- b.) Width - b = 18.75"
- c.) Thickness - This dimension varied slightly from the test plates. Measurements were taken along the edge with a micrometer.

plates were weighed and an average thickness determined assuming a density of steel 0.283 pounds/inches³. The surface of the plates were slightly pitted from corrosion and shot blasting. The depth of pits was determined fairly accurately by measuring the "a"-edge where the surface had been ground to the depth of the pits. An average depth of pits as determined by this method is 0.002". The pitting is fairly evenly distributed over the surface and it is estimated that an average thickness is to one half of the average depth of pits. However the effective thickness of its plates is considered to be the thickness to the bottom of the pits since the lines of stress will not follow the contour of the pits to a marked degree. This same procedure is followed in calculating the value of the modulus of elasticity (E), hence the effect will tend to cancel in the analysis of plate strength.

Plate No.	Weight (lbs)	avg. $\frac{\text{Wgt.}}{\text{plb.}}$ (in)	avg. (micr.) (in)	Pits (in)	avg (corrected) (in)
1	34	.159	.1575	.004	.1535
2	34.2	.160	.1585	.004	.1545
3	33.8	.158	.1585	.004	.1545
4	34.8	.163	.1580	.004	.1540

Nominal thickness of the plate is 0.15625"

Since the scale was accurate to 0.5 pounds and its density of the steel was assumed, it is believed the micrometer readings, even though taken only around the edge of the plate, give a more accurate reading of the plate thickness.

d.) Ratios

"B"-edge Dimension: Defined as the length between "a"-edge supports.

1/4" on each end of the plate was allowed beyond the center line of the

row ball bearings in the "a"-edge support.

$$b = b' - 2 \times 1/4" = 56.25"$$

"A"-edge Dimension: It was considered originally that this dimension should be the over-all width of the plate plus the distance added by inserting the loading segments over the plate edge. The plate sizes were determined on this basis. Further reflection indicated that the true length of the "a"-edge dimension should not include the addition due to the segments. The edge of the plate extends to the center of the segment (minus gasket thickness). The load however is always applied through this center even after deformation since the segment is circular in cross section.

$$a = \text{width of plate} = 13.3125"$$

$$\text{Aspect Ratio} = a/b = \frac{13.3125}{56.25} = 0.237$$

$$\begin{array}{lcl} \text{Thickness Ratio- } a/t = \frac{13.3125}{t} & = & 85.4 \quad \text{Plt. \# 1} \\ & & 84.8 \quad \text{Plt. \# 2} \\ & & 84.8 \quad \text{Plt. \# 3} \\ & & 85.1 \quad \text{Plt. \# 4} \end{array}$$

1. 1944-1945 1946-1947 1948-1949 1950-1951 1952-1953 1954-1955 1956-1957 1958-1959 1960-1961 1962-1963 1964-1965 1966-1967 1968-1969 1970-1971 1972-1973 1974-1975 1976-1977 1978-1979 1980-1981 1982-1983 1984-1985 1986-1987 1988-1989 1990-1991 1992-1993 1994-1995 1996-1997 1998-1999 2000-2001 2002-2003 2004-2005 2006-2007 2008-2009 2010-2011 2012-2013 2014-2015 2016-2017 2018-2019 2020-2021 2022-2023 2024-2025 2026-2027 2028-2029 2030-2031 2032-2033 2034-2035 2036-2037 2038-2039 2040-2041 2042-2043 2044-2045 2046-2047 2048-2049 2050-2051 2052-2053 2054-2055 2056-2057 2058-2059 2060-2061 2062-2063 2064-2065 2066-2067 2068-2069 2070-2071 2072-2073 2074-2075 2076-2077 2078-2079 2080-2081 2082-2083 2084-2085 2086-2087 2088-2089 2090-2091 2092-2093 2094-2095 2096-2097 2098-2099 2100-2101 2102-2103 2104-2105 2106-2107 2108-2109 2110-2111 2112-2113 2114-2115 2116-2117 2118-2119 2120-2121 2122-2123 2124-2125 2126-2127 2128-2129 2130-2131 2132-2133 2134-2135 2136-2137 2138-2139 2140-2141 2142-2143 2144-2145 2146-2147 2148-2149 2150-2151 2152-2153 2154-2155 2156-2157 2158-2159 2160-2161 2162-2163 2164-2165 2166-2167 2168-2169 2170-2171 2172-2173 2174-2175 2176-2177 2178-2179 2180-2181 2182-2183 2184-2185 2186-2187 2188-2189 2190-2191 2192-2193 2194-2195 2196-2197 2198-2199 2200-2201 2202-2203 2204-2205 2206-2207 2208-2209 2210-2211 2212-2213 2214-2215 2216-2217 2218-2219 2220-2221 2222-2223 2224-2225 2226-2227 2228-2229 2230-2231 2232-2233 2234-2235 2236-2237 2238-2239 2240-2241 2242-2243 2244-2245 2246-2247 2248-2249 2250-2251 2252-2253 2254-2255 2256-2257 2258-2259 2260-2261 2262-2263 2264-2265 2266-2267 2268-2269 2270-2271 2272-2273 2274-2275 2276-2277 2278-2279 2280-2281 2282-2283 2284-2285 2286-2287 2288-2289 2290-2291 2292-2293 2294-2295 2296-2297 2298-2299 2300-2301 2302-2303 2304-2305 2306-2307 2308-2309 2310-2311 2312-2313 2314-2315 2316-2317 2318-2319 2320-2321 2322-2323 2324-2325 2326-2327 2328-2329 2330-2331 2332-2333 2334-2335 2336-2337 2338-2339 2340-2341 2342-2343 2344-2345 2346-2347 2348-2349 2350-2351 2352-2353 2354-2355 2356-2357 2358-2359 2360-2361 2362-2363 2364-2365 2366-2367 2368-2369 2370-2371 2372-2373 2374-2375 2376-2377 2378-2379 2380-2381 2382-2383 2384-2385 2386-2387 2388-2389 2390-2391 2392-2393 2394-2395 2396-2397 2398-2399 2400-2401 2402-2403 2404-2405 2406-2407 2408-2409 2410-2411 2412-2413 2414-2415 2416-2417 2418-2419 2420-2421 2422-2423 2424-2425 2426-2427 2428-2429 2430-2431 2432-2433 2434-2435 2436-2437 2438-2439 2440-2441 2442-2443 2444-2445 2446-2447 2448-2449 2450-2451 2452-2453 2454-2455 2456-2457 2458-2459 2460-2461 2462-2463 2464-2465 2466-2467 2468-2469 2470-2471 2472-2473 2474-2475 2476-2477 2478-2479 2480-2481 2482-2483 2484-2485 2486-2487 2488-2489

1950 = 1950 = 1950 = 1950 = 1950 =

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$$\frac{\partial \mathcal{L}}{\partial \mathbf{w}} = \frac{\partial \mathcal{L}}{\partial \mathbf{z}} \frac{\partial \mathbf{z}}{\partial \mathbf{w}} = 0$$

$\frac{1}{2} = \frac{1}{2} = 1$ - other things

$$E_{\text{eff}} = \frac{E}{1 + \frac{1}{\beta}} = \frac{E}{1 + \frac{1}{\beta}}$$

$\frac{d}{dt} \left(\frac{\partial L}{\partial \dot{x}} \right) = \frac{\partial L}{\partial x}$

1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29. 30. 31. 32. 33. 34. 35. 36. 37. 38. 39. 40. 41. 42. 43. 44. 45. 46. 47. 48. 49. 50. 51. 52. 53. 54. 55. 56. 57. 58. 59. 60. 61. 62. 63. 64. 65. 66. 67. 68. 69. 70. 71. 72. 73. 74. 75. 76. 77. 78. 79. 80. 81. 82. 83. 84. 85. 86. 87. 88. 89. 90. 91. 92. 93. 94. 95. 96. 97. 98. 99. 100. 101. 102. 103. 104. 105. 106. 107. 108. 109. 110. 111. 112. 113. 114. 115. 116. 117. 118. 119. 120. 121. 122. 123. 124. 125. 126. 127. 128. 129. 130. 131. 132. 133. 134. 135. 136. 137. 138. 139. 140. 141. 142. 143. 144. 145. 146. 147. 148. 149. 150. 151. 152. 153. 154. 155. 156. 157. 158. 159. 160. 161. 162. 163. 164. 165. 166. 167. 168. 169. 170. 171. 172. 173. 174. 175. 176. 177. 178. 179. 180. 181. 182. 183. 184. 185. 186. 187. 188. 189. 190. 191. 192. 193. 194. 195. 196. 197. 198. 199. 200. 201. 202. 203. 204. 205. 206. 207. 208. 209. 210. 211. 212. 213. 214. 215. 216. 217. 218. 219. 220. 221. 222. 223. 224. 225. 226. 227. 228. 229. 230. 231. 232. 233. 234. 235. 236. 237. 238. 239. 240. 241. 242. 243. 244. 245. 246. 247. 248. 249. 250. 251. 252. 253. 254. 255. 256. 257. 258. 259. 260. 261. 262. 263. 264. 265. 266. 267. 268. 269. 270. 271. 272. 273. 274. 275. 276. 277. 278. 279. 280. 281. 282. 283. 284. 285. 286. 287. 288. 289. 290. 291. 292. 293. 294. 295. 296. 297. 298. 299. 300. 301. 302. 303. 304. 305. 306. 307. 308. 309. 310. 311. 312. 313. 314. 315. 316. 317. 318. 319. 320. 321. 322. 323. 324. 325. 326. 327. 328. 329. 330. 331. 332. 333. 334. 335. 336. 337. 338. 339. 340. 341. 342. 343. 344. 345. 346. 347. 348. 349. 350. 351. 352. 353. 354. 355. 356. 357. 358. 359. 360. 361. 362. 363. 364. 365. 366. 367. 368. 369. 370. 371. 372. 373. 374. 375. 376. 377. 378. 379. 380. 381. 382. 383. 384. 385. 386. 387. 388. 389. 390. 391. 392. 393. 394. 395. 396. 397. 398. 399. 400. 401. 402. 403. 404. 405. 406. 407. 408. 409. 410. 411. 412. 413. 414. 415. 416. 417. 418. 419. 420. 421. 422. 423. 424. 425. 426. 427. 428. 429. 430. 431. 432. 433. 434. 435. 436. 437. 438. 439. 440. 441. 442. 443. 444. 445. 446. 447. 448. 449. 450. 451. 452. 453. 454. 455. 456. 457. 458. 459. 460. 461. 462. 463. 464. 465. 466. 467. 468. 469. 470. 471. 472. 473. 474. 475. 476. 477. 478. 479. 480. 481. 482. 483. 484. 485. 486. 487. 488. 489. 490. 491. 492. 493. 494. 495. 496. 497. 498. 499. 500. 501. 502. 503. 504. 505. 506. 507. 508. 509. 510. 511. 512. 513. 514. 515. 516. 517. 518. 519. 520. 521. 522. 523. 524. 525. 526. 527. 528. 529. 530. 531. 532. 533. 534. 535. 536. 537. 538. 539. 540. 541. 542. 543. 544. 545. 546. 547. 548. 549. 550. 551. 552. 553. 554. 555. 556. 557. 558. 559. 560. 561. 562. 563. 564. 565. 566. 567. 568. 569. 570. 571. 572. 573. 574. 575. 576. 577. 578. 579. 580. 581. 582. 583. 584. 585. 586. 587. 588. 589. 590. 591. 592. 593. 594. 595. 596. 597. 598. 599. 600. 601. 602. 603. 604. 605. 606. 607. 608. 609. 610. 611. 612. 613. 614. 615. 616. 617. 618. 619. 620. 621. 622. 623. 624. 625. 626. 627. 628. 629. 630. 631. 632. 633. 634. 635. 636. 637. 638. 639. 640. 641. 642. 643. 644. 645. 646. 647. 648. 649. 650. 651. 652. 653. 654. 655. 656. 657. 658. 659. 660. 661. 662. 663. 664. 665. 666. 667. 668. 669. 670. 671. 672. 673. 674. 675. 676. 677. 678. 679. 680. 681. 682. 683. 684. 685. 686. 687. 688. 689. 690. 691. 692. 693. 694. 695. 696. 697. 698. 699. 700. 701. 702. 703. 704. 705. 706. 707. 708. 709. 710. 711. 712. 713. 714. 715. 716. 717. 718. 719. 720. 721. 722. 723. 724. 725. 726. 727. 728. 729. 730. 731. 732. 733. 734. 735. 736. 737. 738. 739. 740. 741. 742. 743. 744. 745. 746. 747. 748. 749. 750. 751. 752. 753. 754. 755. 756. 757. 758. 759. 760. 761. 762. 763. 764. 765. 766. 767. 768. 769. 770. 771. 772. 773. 774. 775. 776. 777. 778. 779. 780. 781. 782. 783. 784. 785. 786. 787. 788. 789. 790. 791. 792. 793. 794. 795. 796. 797. 798. 799. 800. 801. 802. 803. 804. 805. 806. 807. 808. 809. 810. 811. 812. 813. 814. 815. 816. 817. 818. 819. 820. 821. 822. 823. 824. 825. 826. 827. 828. 829. 830. 831. 832. 833. 834. 835. 836. 837. 838. 839. 840. 84

Technical drawing of a rectangular frame structure, likely a bridge or a large window frame, showing dimensions and load indicators.

Dimensions:

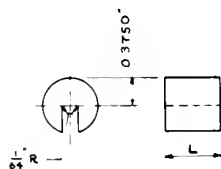
- Overall width: 60 ft.
- Overall height: 24 ft.
- Internal horizontal dimensions (from left to right): 3', 9', 15', 9', 9', 9', 9', 3'.
- Internal vertical dimensions (from bottom to top): 2', 4', 9', 9', 9', 9', 4', 2'.

Structural Features:

- The structure consists of a grid of vertical and horizontal members.
- Vertical members are supported by a series of columns at the bottom.
- Horizontal members are connected by a series of beams.
- Diagonal bracing is present in the central panels.

Load Indicators:

- Two arrows labeled "B" point downwards from the top and bottom center of the structure, indicating a vertical load or reaction.



A schematic diagram showing a cross-section of a mechanical assembly. A circular component labeled 'SEGMENT' is shown with a hatched pattern. Below it is a 'GASKET' layer, followed by 'SHIMS' (two thin layers). At the bottom is a 'TEST PLT' (test plate). Arrows point from the labels to their respective components.

"B"-EDGE BEARING SEGMENTS
MATL: $\frac{3}{4}$ " DRILL ROD
MILLED & HARDENED TO ROCKWELL C-50

DETAILS OF LOADING ARRANGEMENT

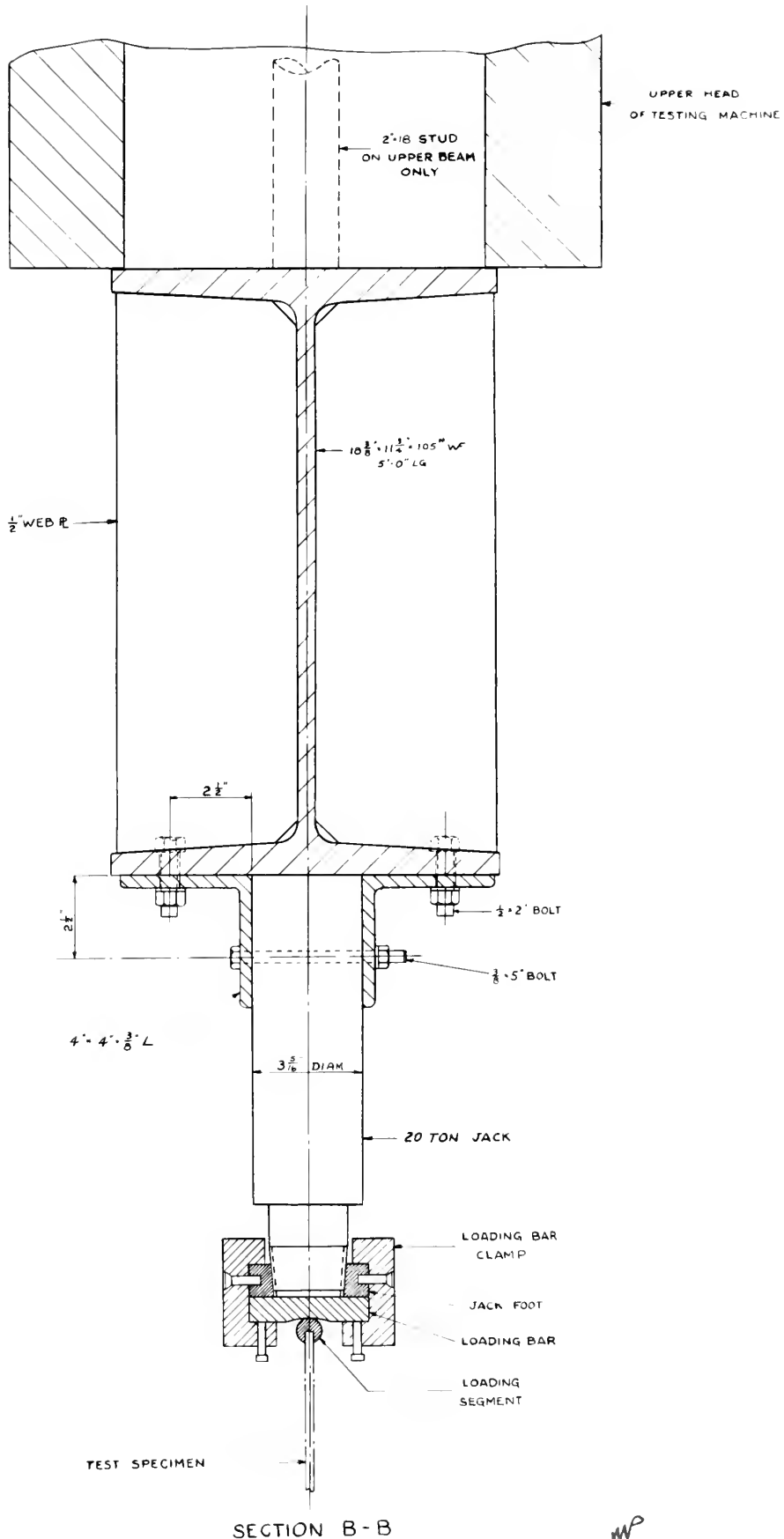
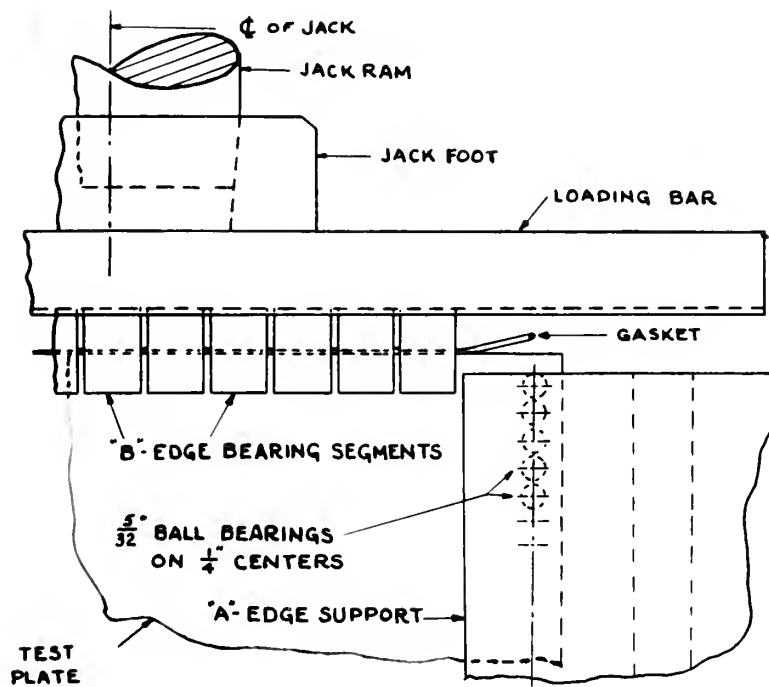


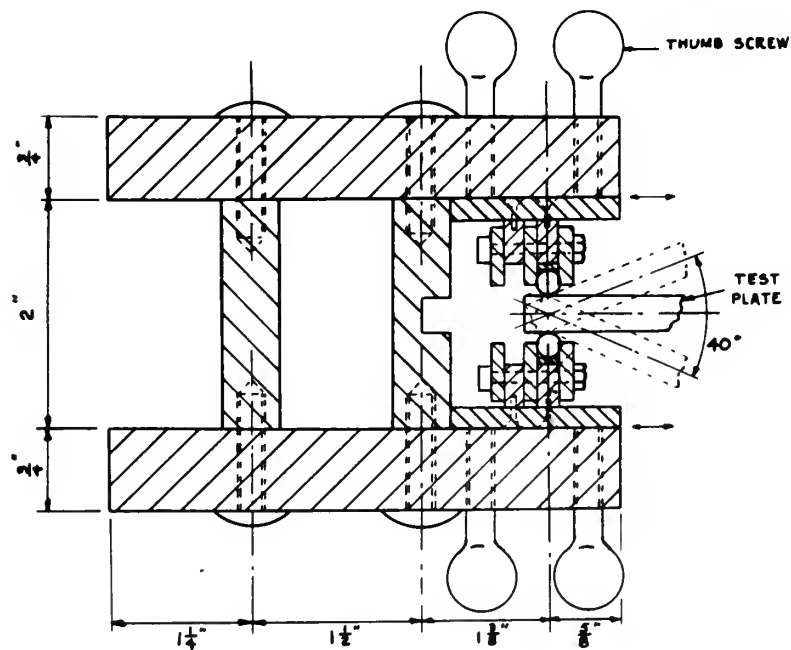
FIG.
DETAILS OF LOADING ARRANGEMENT



DETAIL AT CORNER OF TEST PLATE

DRAWN TO SCALE

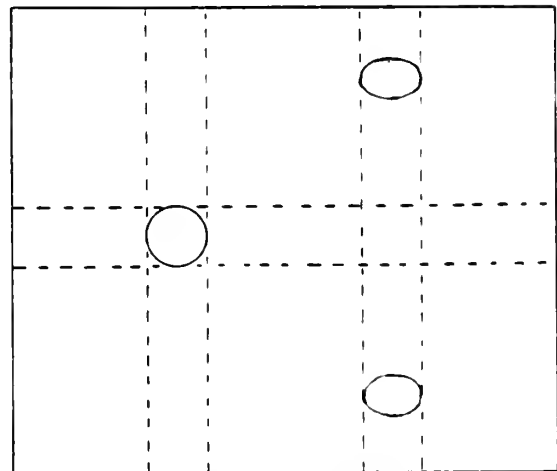
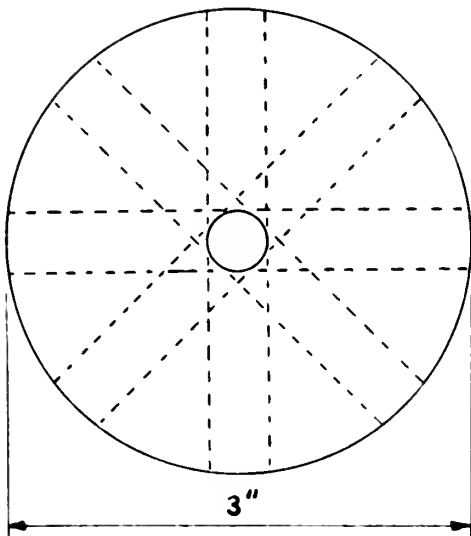
1"



CROSSSECTION OF "A"-EDGE SUPPORT

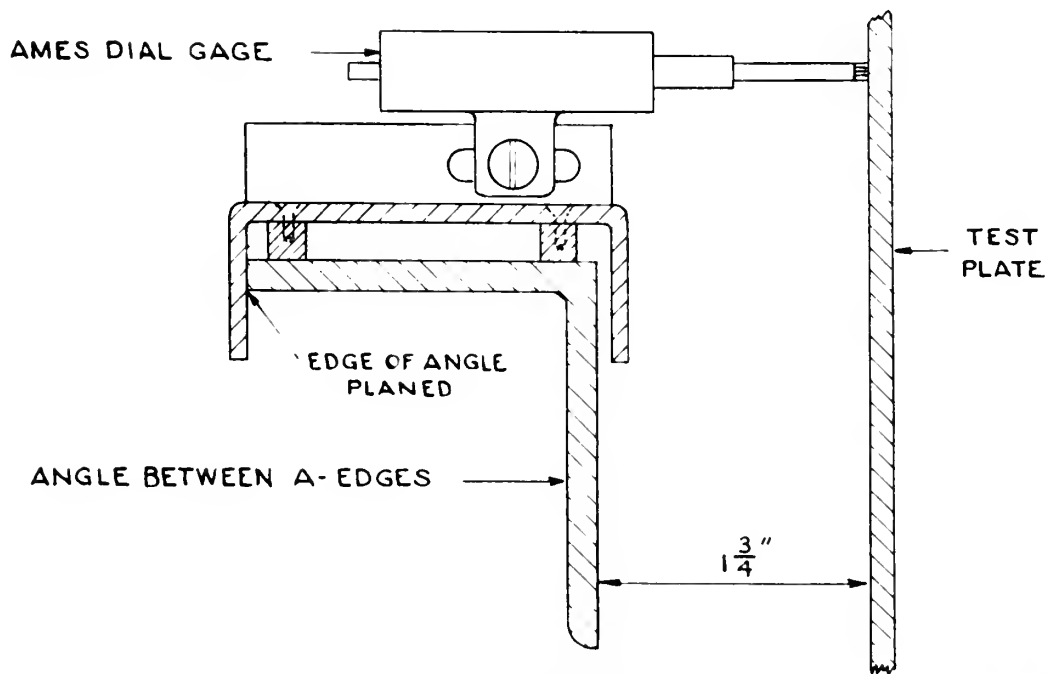
5/7/54 MP

FIG. 30
DETAILS OF LOADING ARRANGEMENT



ALL HOLES TAPPED FOR $\frac{3}{8}$ " STD. PIPE THR.

MANIFOLD



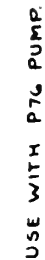
DEFLECTOMETER

5/16/54 M

MILWAUKEE, WIS.

ENG. DEPT.

OCT. 23, 1941.



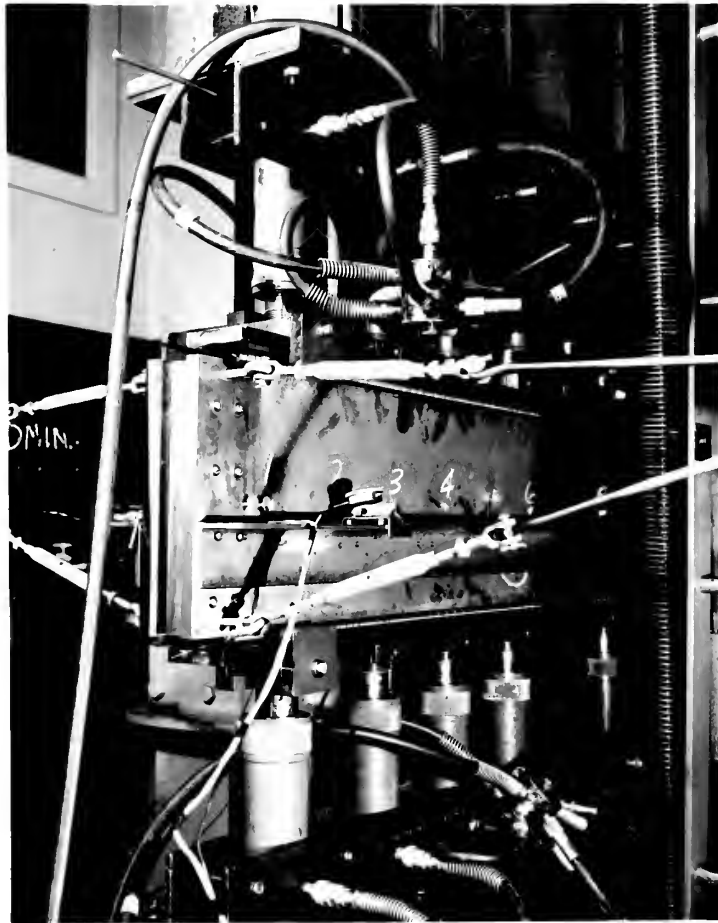
163 STROKES FOR TOTAL TRAVEL OF 5062"
031 INCH PER STROKE OF P76 PUMP
INTERNAL PRESSURE AT RATED CAPACITY OF
7750 LBS. PER SQ INCH.
HANDLE EFFORT ON PUMP 89 LBS.

R 225 RAM WEIGHT 20 1/4 LBS
R 251 RAM WEIGHT 21 1/2 LBS
RATED CAPACITY 20 TON
RAM DIA. 2.562"
RAM TRAVEL 5.062"
RAM AREA 5.1572 SQ. IN.
OIL CAPACITY 26.1 CU. IN.

SHEET NO.

FIGURE NO. 32

TEST APPARATUS



FROM DEPT

SECRETARY

FIGURE NO. 33
TEST APPARATUS



THE JON JENCKE

RESEARCH TEST

C. Summary of Data and Calculations

Table III A

Evaluation Tests

P = 20,000 lb. $\epsilon_{av} = 81.1$ in./in.

| Test No. | * | ϵ_{av} | Lowest ϵ_a | % under | Highest ϵ_a | % over | Max. % |
|----------|---|-----------------|---------------------|---------|----------------------|--------|--------|
| 1 | T | 85.5 | 46.5 | 42.7 | 153.0 | 88.6 | 88.6 |
| | B | 78.0 | 35.0 | 56.9 | 152.0 | 87.5 | |
| 4 | T | 82.2 | 48.0 | 40.8 | 126.5 | 56.0 | 56.0 |
| | B | 69.7 | 39.5 | 51.4 | 94.5 | 16.6 | |
| 5 | T | 76.9 | 51.5 | 36.6 | 94.5 | 16.6 | 43.9 |
| | B | 70.1 | 45.5 | 43.9 | 102 | 25.8 | |
| 6 | T | 76.1 | 48 | 40.8 | 110.5 | 36.3 | 40.8 |
| | B | 69.0 | 47.5 | 41.5 | 96.5 | 19.0 | |
| 7 | T | 69.8 | 34.5 | 57.5 | 97.0 | 19.6 | 71.0 |
| | B | 71.2 | 23.5 | 71.0 | 105.0 | 29.5 | |
| 13 | T | 81.7 | 55.5 | 31.6 | 111 | 36.9 | 49.3 |
| | B | 78.1 | 47.0 | 42.1 | 121 | 49.3 | |
| 14 | T | 78.0 | 47.0 | 42.1 | 138.5 | 70.8 | 70.8 |
| | B | 72.6 | 52 | 35.9 | 95.5 | 17.8 | |
| 15 | T | 66.1 | 22 | 73.0 | 118.5 | 46.2 | 74.8 |
| | B | 62.7 | 20.5 | 74.8 | 88.0 | 8.5 | |
| 16 | T | 72.0 | 52.5 | 35.3 | 145.5 | 79.4 | 79.4 |
| | B | 72.4 | 26 | 68.0 | 112.5 | 38.8 | |
| 17 | T | 69.3 | 35 | 56.9 | 118.5 | 46.2 | 81.5 |
| | B | 64.1 | 15 | 81.5 | 120.5 | 48.6 | |
| 18 | T | 70.9 | 29 | 64.3 | 106 | 30.7 | 79.1 |
| | B | 70.2 | 17 | 79.1 | 112.5 | 38.8 | |

* T - Top of plate ; B - Bottom of plate

Table III A

Washington State

3 = 20,000 lb. 2 = 10,000 lb. 1 = 5,000 lb.

| Test No. | * | 3 in | Lowest 3 | 2 in | Highest 3 | 2 in | 3 in |
|----------|---|------|----------|------|-----------|------|------|
| 1 | T | 82.2 | 40.2 | 43.1 | 123.0 | 38.1 | 38.8 |
| | B | 78.0 | 35.0 | 22.2 | 123.0 | 37.1 | |
| 2 | T | 82.2 | 48.0 | 40.8 | 130.2 | 36.0 | 30.0 |
| | B | 69.1 | 32.2 | 21.2 | 80.2 | 30.0 | |
| 3 | T | 80.9 | 21.2 | 30.2 | 84.2 | 31.1 | 33.2 |
| | B | 70.1 | 12.2 | 13.2 | 102 | 24.2 | |
| 4 | T | 74.1 | 18 | 40.8 | 170.1 | 22.0 | 40.9 |
| | B | 69.0 | 11.2 | 11.2 | 90.2 | 23.1 | |
| 5 | T | 69.8 | 34.2 | 21.2 | 81.0 | 21.0 | 41.0 |
| | B | 71.2 | 23.2 | 12.0 | 102.0 | 24.2 | |
| 6 | T | 61.1 | 22.2 | 27.0 | 111 | 30.2 | 40.2 |
| | B | 48.1 | 12.0 | 12.1 | 121 | 23.2 | |
| 7 | T | 78.0 | 41.0 | 42.1 | 130.2 | 30.2 | 40.2 |
| | B | 72.4 | 22 | 32.2 | 82.2 | 21.1 | |
| 8 | T | 66.1 | 22 | 42.0 | 172.2 | 20.0 | 40.0 |
| | B | 62.1 | 20.2 | 12.2 | 80.0 | 20.0 | |
| 9 | T | 72.0 | 22.2 | 32.2 | 112.2 | 22.0 | 42.0 |
| | B | 72.4 | 22 | 20.0 | 112.2 | 20.0 | |
| 10 | T | 60.3 | 22 | 20.2 | 110.2 | 21.1 | 41.1 |
| | B | 61.1 | 12 | 20.2 | 120.2 | 14.0 | |
| 11 | T | 70.2 | 22 | 20.2 | 102 | 20.0 | 40.0 |
| | B | 70.2 | 12 | 20.2 | 122.2 | 20.0 | |

* T = Top of plate; B = Bottom of plate

Table III B
Buckling Tests

| Plate No. | 1 | 2 | 3 | 4 |
|---|--------|--------|--------|--------|
| a (in.) | 13.313 | 13.313 | 13.313 | 13.313 |
| b (in.) | 56.75 | 56.75 | 56.75 | 56.75 |
| t (in.) | 0.1535 | 1.545 | 1.545 | 1.540 |
| a/b | 0.237 | 0.237 | 0.237 | 0.237 |
| a/t | 86.8 | 86.2 | 86.2 | 86.5 |
| b/t | 370 | 367 | 367 | 368 |
| d_0 (measured) (in.) | 0.085 | 0.057 | 0.009 | 0.071 |
| d_0 (Donnell) (in.) | 0.038 | 0.059 | 0.018 | 0.060 |
| d_0 (Southwell) (in.) | 0.044 | 0.061 | 0.019 | 0.062 |
| σ_{ult} (exp.) (psi) | 4140 | 3375 | 3720 | 3830 |
| σ_{cr} (Theory) (psi) | 3780 | 3830 | 3830 | 3810 |
| σ_{cr} ("T.O.K.") (psi) | 3730 | 2620 | 3210 | 3190 |
| σ_{cr} (Donnell) (psi) | 4640 | 3530 | 3580 | 4120 |
| σ_{cr} (Southwell) (psi) | 4520 | 3540 | 3635 | 3940 |
| $\frac{\text{Donnell} - \text{Bleich} \times 100}{\text{Bleich}}$ | + 23.4 | -7.83 | -6.53 | + 7.61 |

Table III B
 Housing Costs

| State No. | I | II | III | IV |
|---|--------|--------|--------|--------|
| a (1st) | 13.313 | 13.313 | 13.313 | 13.313 |
| b (1st) | 26.17 | 26.17 | 26.17 | 26.17 |
| c (1st) | 0.1532 | 1.532 | 1.532 | 1.532 |
| d | 0.531 | 0.531 | 0.531 | 0.531 |
| e | 66.8 | 66.8 | 66.8 | 66.8 |
| f | 370 | 370 | 370 | 370 |
| g (1st) (1st) | 0.081 | 0.081 | 0.081 | 0.081 |
| g (1st) (1st) | 0.038 | 0.038 | 0.038 | 0.038 |
| g (1st) (1st) | 0.025 | 0.025 | 0.025 | 0.025 |
| h (1st) (1st) | 4115 | 3772 | 3772 | 3830 |
| i (1st) (1st) | 3780 | 3638 | 3638 | 3610 |
| j (1st) (1st) | 3730 | 3680 | 3680 | 3730 |
| k (1st) (1st) | 4010 | 3730 | 3730 | 4030 |
| l (1st) (1st) | 4250 | 410 | 410 | 3950 |
| Housing Costs - 100
+ 100
+ 100
+ 100
+ 100 | | | | |

D. SAMPLE CALCULATIONS

1. The longitudinal strain in the plate at a given point on its neutral axis was obtained by averaging the strains obtained from a pair of gages mounted on opposite sides of the plate and opposite each other as shown on Fig. 15. All odd numbered gages were on one side of the plate, and all even numbered gages were on the other, the arrangement being such that each odd gage had opposite it the gage with the next highest even number.

$$\epsilon_a = \frac{\epsilon_1 + \epsilon_2}{2}$$

Thus for gage numbers 67 and 68 in Test No. 19 on Plate No. 1, at a load of 20,000 pounds,

$$\epsilon_1 = +181 \text{ microinches/inch}$$

$$\epsilon_2 = -359 \text{ microinches/inch}$$

$$\epsilon_a = \frac{(+181) + (-359)}{2} = -89 \text{ microinches/inch}$$

2. The average longitudinal stress in the plate was obtained by dividing the total applied load by the edge area of the plate.

$$\sigma_{av} = \frac{P}{b^1 t}$$

For Test No. 19 on Plate No. 1 at a load of 20,000 pounds,

$$P = 20,000 \text{ lbs.}$$

$$b^1 = 56.75 \text{ in.}$$

$$t = 0.1535 \text{ in.}$$

$$\sigma_{av} = \frac{20,000}{(56.75)(0.1535)} = 2295 \text{ psi}$$

For the same test, at the critical load,

$$P_{cr} = 40,400 \text{ lbs. (Donnell)}$$

$$\sigma_{av} = \frac{40,400}{(56.75)(0.1535)} = 4640 \text{ psi}$$

3. SAMPLE CALCULATION

1. The longitudinal strains in the plates at a given point in the longitudinal axis was obtained by averaging the strains measured at the points in the plates mounted on opposite sides of the plate and adjacent to each other as shown on Fig. 12. All odd numbered gages were on one side of the plate and all even numbered gages were on the other. The average longitudinal strain was found each odd gage and opposite it the gage with the next highest strain number.

$$\frac{313 + 313}{2} = 313$$

Then for gage numbers 67 and 68 in Test No. 12 no plate No. 12 is used of 20,000 pounds.

$$E_1 = +161 \text{ micro-inches/inch}$$

$$E_2 = -152 \text{ micro-inches/inch}$$

$$E_3 = \frac{(+161) + (-152)}{2} = 4.5 \text{ micro-inches/inch}$$

2. The average longitudinal strains in the plates was found by averaging the total applied load by the area of the plates.

$$\bar{E} = \frac{E_1 + E_2 + E_3}{3}$$

For Test No. 12 on plate No. 1 as a load of 20,000 lb.

$$P = 20,000 \text{ lbs.}$$

$$A = 20.75 \text{ in.}^2$$

$$S = 0.1525 \text{ in.}$$

$$\bar{E} = \frac{20,000}{(20.75)(0.1525)} = 632 \text{ psi}$$

For the same test, in the vertical direction

$$E_1 = 14,400 \text{ psi. (compressive)}$$

$$\bar{E} = \frac{10,400}{(20.75)(0.1525)} = 332 \text{ psi}$$

3. Average strain was calculated using the stresses obtained above and the value of E obtained from Appendix F.

$$\epsilon_{av} = \frac{\sigma_{av}}{E}$$

$$E = 28,300,000 \text{ psi}$$

At 20,000 pounds,

$$\epsilon_{av} = \frac{2295}{28,300,000} = 81.1 \text{ microinches/inch}$$

A different value for ϵ_{av} is obtained if the plot of axial strain (ϵ_a) is integrated by the trapezoidal rule along the line of gages, numbers 7, 8 through 35, 36. (A value of 81.1 will be assumed for the axial strain at gages 35 and 36, since no readings were obtained at these gages for this test.)

$$\epsilon_{av} = \frac{1}{14} \left[\frac{1}{2} \epsilon_a(7,8) + \sum_{(9,10)}^{(33,34)} \epsilon_a + \frac{1}{2} \epsilon_a(35,36) \right]$$

$$\epsilon_{av} = \frac{1}{14} (1046.6) = 74.8 \text{ microinches/inch}$$

4. Percentage of maximum deviation of axial strain from average strain as computed from the total load.

$$\% = \frac{\sum \epsilon_a - \epsilon_{av}}{\epsilon_{av}} \times 100$$

$$\epsilon_{av} = \frac{P}{E A_0} = 81.1 \text{ microinches/inch}$$

$$\epsilon_{a \text{ max}} = 116 \text{ microinches/inch}$$

$$\epsilon_{a \text{ min}} = 50 \text{ microinches/inch}$$

$$\text{Max } \% \text{ over} = \frac{116-81.1}{81.1} \times 100 = 43.0\% \text{ over}$$

$$\text{Max } \% \text{ under} = \frac{50-81.1}{81.1} \times 100 = 38.4\% \text{ over}$$

3. Average strain was calculated using the following equation and the value of ϵ obtained from equation 2.

$$\bar{\epsilon} = \frac{\sum \epsilon_i}{n}$$

$$\bar{\epsilon} = \frac{30,000,000}{30,000,000}$$

$$\bar{\epsilon} = 1.0$$

$$\bar{\epsilon} = \frac{30,000,000}{30,000,000} = 1.0$$

A different value for $\bar{\epsilon}$ is obtained in the case of other values of ϵ . The value of $\bar{\epsilon}$ is obtained by the following equation and the value of ϵ is obtained from equation 2. (A value of $\bar{\epsilon}$ will be obtained for the value of ϵ obtained from equation 2 and $\bar{\epsilon}$ will be obtained from equation 2.)

$$\bar{\epsilon} = \frac{1}{n} \left[\frac{1}{2} \left(\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} \right) + \frac{1}{2} \left(\frac{1}{\epsilon_2} + \frac{1}{\epsilon_3} \right) + \dots + \frac{1}{2} \left(\frac{1}{\epsilon_{n-1}} + \frac{1}{\epsilon_n} \right) \right]$$

$$\bar{\epsilon} = \frac{1}{n} \left[\frac{1}{2} \left(\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} \right) + \dots + \frac{1}{2} \left(\frac{1}{\epsilon_{n-1}} + \frac{1}{\epsilon_n} \right) \right]$$

4. The average of maximum strain of all the values of ϵ is obtained from the following equation.

$$\bar{\epsilon}_{max} = \frac{\sum \epsilon_{max}}{n}$$

$$\bar{\epsilon}_{max} = \frac{30,000,000}{30,000,000}$$

$$\bar{\epsilon}_{max} = 1.0$$

$$\bar{\epsilon}_{max} = 1.0$$

$$\bar{\epsilon}_{max} = \frac{30,000,000}{30,000,000}$$

$$\bar{\epsilon}_{max} = \frac{30,000,000}{30,000,000}$$

5. Strain difference (proportional to lateral deflection) was obtained by subtracting readings of opposite gages. Arbitrarily this was taken as

$$\varepsilon_2 - \varepsilon_1 = \varphi(d)$$

For Test No. 19 on Plate No. 1, using the values in (1) above,

$$\varepsilon_2 - \varepsilon_1 = -359 - (+181) = -540 \text{ microinches/inch}$$

6. Critical load (Top-of-the-Knee Method). To obtain this value no calculations other than those given above for σ_{cr} and $(\varepsilon_2 - \varepsilon_1)$ were necessary. After plotting σ_{cr} vs. $(\varepsilon_2 - \varepsilon_1)$ the tangents at the extremities of the curve were drawn. The intersection was taken as the buckling point.

$$\sigma_{cr} = 3730 \text{ psi}$$

7. Critical load (Southwell's Method).

$$\varepsilon_2 - \varepsilon_1 = \varphi(d)$$

$$\frac{\varepsilon_2 - \varepsilon_1}{P} = \frac{\varphi(d)}{\text{Load}}$$

For gages number 67 and 68 in Test No. 19, Plate No. 1 at a load of 20,000 pounds,

$$P = 20,000 \text{ lbs.}$$

$$\varepsilon_2 - \varepsilon_1 = -540 \text{ microinches/inch (from above)}$$

$$\frac{\varepsilon_2 - \varepsilon_1}{P} = \frac{540}{20,000} = 0.0270$$

A plot of $\frac{\varepsilon_2 - \varepsilon_1}{P}$ vs. $\varepsilon_2 - \varepsilon_1$ gives a straight line with a slope

equal to the critical load.

2. Stress distribution (superposition of internal and external) was obtained by subtracting results of opposite signs. Additionally this was taken

$$(h) \varphi = 13 - 3$$

For test No. 13 on plate No. 1, using the values in Table 1.

$$\sigma_{\text{residual}} = (121 +) - 22 = 99$$

3. Critical load (Top-of-the-Race Method). To obtain this value

calculations were then given above for $(13 - 3)$ and $(13 - 3)$ were

necessary. After plotting σ_{residual} vs. $(13 - 3)$ the straight line was

drawn. The intersection was taken as the buckling point.

$$\sigma_{\text{residual}} = 13 - 3$$

4. Critical load (Bortolotti's Method).

$$(h) \varphi = 13 - 3$$

$$\frac{(h) \varphi}{\text{load}} = \frac{13 - 3}{1}$$

For given number of and in test No. 13, Table No. 1 and a load of

50,000 pounds

$$P = 50,000 \text{ lbs.}$$

$$\sigma_{\text{residual}} = 13 - 3$$

$$0.0210 = \frac{0.0210}{50,000} = 13 - 3$$

A line was drawn through the points $(13 - 3)$ and $(13 - 3)$ and the intersection

point was taken as the critical load.

$$P_{cr} = \frac{\partial[(\epsilon_2 - \epsilon_1)]}{\partial[(\epsilon_2 - \epsilon_1)/P]}$$

$$P_{cr} = 39,400 \text{ lbs.}$$

$$\sigma_{cr} = \frac{P_{cr}}{b'xt} = 4520 \text{ psi}$$

The intercept of the straight line with the $(\epsilon_2 - \epsilon_1)$ axis represents an equivalent initial deflection of the plate.

$$(\epsilon_2 - \epsilon_1)_0 = 355 \text{ microinches/inch}$$

$$w = d_0 \sin \frac{\pi x}{L}$$

$$M_x = -D \frac{\partial^2 w}{\partial x^2} = D d_0 \frac{\pi^2}{L^2} \sin \frac{\pi x}{L}$$

$$M_x = D d_0 \frac{\pi^2}{L^2} \text{ when } x = \frac{L}{2}$$

$$\sigma_{max} = \frac{M_x t}{2 I} = \frac{E(\epsilon_2 - \epsilon_1)}{2}$$

$$M_x = \frac{EI(\epsilon_2 - \epsilon_1)}{t}$$

$$D = \frac{Et^3}{12(1-\nu^2)} = \frac{EI}{1-\nu^2}$$

$$\frac{EI}{1-\nu^2} \frac{\pi^2}{L^2} d_0 = \frac{EI(\epsilon_2 - \epsilon_1)}{t}$$

$$d_0 = \frac{(1-\nu^2) L^2}{\pi^2 t} (\epsilon_2 - \epsilon_1)$$

$$\nu = 0.3$$

$$L = 13.313 \text{ in.}$$

$$t = 0.1535 \text{ in.}$$

$$(\epsilon_2 - \epsilon_1) = 355 \times 10^{-6} \text{ in./in (from above)}$$

$$d_0 = \frac{0.91}{\pi^2} \frac{(13.313)^2}{0.1535} (355 \times 10^{-6}) = 0.0378 \text{ in.}$$

$$\frac{9[(3-2)]}{9[(3-2)]} = 9$$

$$P_{100} = 100$$

$$100000 = \frac{100}{100000} = 100$$

The intercept of the straight line with the y-axis represents the initial value of the variable.

and the slope of the line represents the rate of change of the variable.

$$y = 100000 - 1000x$$

$$y = 100000 - 1000x$$

$$y = 100000 - 1000x$$

$$y = 100000 - 1000x$$

$$y = 100000 - 1000x$$

$$y = 100000 - 1000x$$

$$y = 100000 - 1000x$$

$$y = 100000 - 1000x$$

$$y = 100000 - 1000x$$

$$y = 100000 - 1000x$$

$$y = 100000 - 1000x$$

$$y = 100000 - 1000x$$

$$y = 100000 - 1000x$$

$$y = 100000 - 1000x$$

8. Critical load (Donnell's Method). Donnell's type of plot determines the critical load directly as the intercept on the P-axis of the plot of P vs. $P/(\epsilon_2 - \epsilon_1)$.

For Test No. 19, Plate No. 1,

$$P_{cr} = 40,400 \text{ lbs.}$$

$$\sigma_{cr} = \frac{P_{cr}}{b \cdot t} = 4640 \text{ psi}$$

The slope of the plot is the equivalent initial deflection

$$(\epsilon_2 - \epsilon_1)_0 = \frac{\Delta [P]}{\Delta [P/(\epsilon_2 - \epsilon_1)]} = 415 \text{ microinches/inch}$$

$$d_0 = 0.0442 \text{ in.}$$

9. Theoretical Critical Stress

$$a. \quad \frac{\sigma_{cr}}{\tau} = \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{a}\right)^2 \frac{1}{k}$$

$$E = 28,300,000 \text{ lbs/in.}^2$$

$$\nu = 0.3 \text{ (assumed)}$$

$$a = 13.313 \text{ in.}$$

$$b = 56.25 \text{ in.}$$

$$\frac{a}{b} = 0.237$$

$$K = 1.113 \text{ (Table 40, p. 436)}$$

$$\tau = 1.000$$

$$\sigma_{cr} = 160,400 \text{ psi}$$

| Plate No. | t (in.) | σ_{cr} (psi) |
|-----------|---------|---------------------|
| 1 | .1535 | 3780 |
| 2 | .1545 | 3830 |
| 3 | .1545 | 3830 |
| 4 | .1540 | 3810 |

8. Critical load (Rankine's method). Rankine's type of plate deformation
 the critical load directly as the function of the ratio of the plate to
 the ratio $\lambda = \frac{b}{a}$.

For test No. 19, Plate No. 1.

$$P_{cr} = 10,100 \text{ lbs.}$$

$$\sigma_{cr} = \frac{P_{cr}}{A} = 16,100 \text{ psi}$$

The slope of the plot in the equivalent initial deflection

$$\frac{d\sigma_{cr}}{d\lambda} = \frac{b \left[\frac{d}{a} \right]}{b \left[\frac{d}{a} \right]} = 0.13$$

$$d\sigma_{cr} = 0.013 \text{ ksi}$$

9. Theoretical Critical Stress

$$\sigma_{cr} = \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{a} \right)^2$$

$$E = 28,000,000 \text{ lbs./in.}^2$$

$$\nu = 0.3 \text{ (assumed)}$$

$$a = 13.375 \text{ in.}$$

$$t = 0.125 \text{ in.}$$

$$\sigma_{cr} = 0.137$$

$$E = 1.11 \text{ (ratio to } E \text{ of No. 1)}$$

$$t = 1.000$$

$$\sigma_{cr} = 10,100 \text{ psi}$$

| Plate No. | λ | σ_{cr} (ksi) |
|-----------|-----------|---------------------|
| 1 | 1.11 | 10.1 |
| 2 | 1.11 | 10.1 |
| 3 | 1.11 | 10.1 |
| 4 | 1.11 | 10.1 |

$$b. \quad \sigma_{cr} = \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{b} \right)^2 k \quad (3)$$

where $E = 28,300 \text{ lb./in.}^2$

$$\nu = 0.3$$

$$a = 13.313 \text{ in.}$$

$$b = 56.25 \text{ in.}$$

$$\alpha = \frac{a}{b} = 0.237$$

$$k = \left(\frac{\alpha}{n} + \frac{n}{\alpha} \right)^2 \quad \text{for plates simply supported on all four edges}$$

$$n = 1$$

$$k = \left(\frac{0.237}{1} + \frac{1}{0.237} \right)^2 = 19.90$$

$$\sigma_{cr} = 161,000 \text{ t}^2$$

| Plate No. | σ_{cr} (psi) |
|-----------|---------------------|
| 1 | 3790 |
| 2 | 3840 |
| 3 | 3840 |
| 4 | 3820 |

10. Modulus of Elasticity

For specimen number 1:

$$l = 2.547 \text{ in.} \quad \text{Huggenberger G. F. (\#1) = 1051}$$

$$w = 0.8435 \text{ in.} \quad \text{Huggenberger G. F. (\#2) = 1040}$$

$$t = 0.1572 \text{ in.}$$

$$\text{At } P = 0: \quad R_1 = 1.55$$

$$R_2 = 1.51$$

$$\text{At } P = 2160 \text{ lbs.:} \quad R_1 = 1.09$$

$$R_2 = 0.86$$

(a)

$$\Delta = \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{a}{b} \right)^2$$

$$\text{where } E = 28,700 \text{ lb./in.}^2$$

$$\nu = 0.2$$

$$a = 13.373 \text{ in.}$$

$$b = 20.52 \text{ in.}$$

$$\alpha = \frac{a}{b} = 0.651$$

$$\text{For plates rigidly supported on all four edges}$$

$$k = \left(\frac{\alpha}{2} + \frac{2}{\alpha} \right)^2$$

$$k = \left(\frac{0.651}{2} + \frac{2}{0.651} \right)^2 = 12.90$$

$$\Delta_{cr} = 1407,000 \text{ lb.}$$

Plate No. Δ_{cr} (lb.)

$$1 \quad 3720$$

$$2 \quad 3610$$

$$3 \quad 3510$$

$$4 \quad 3320$$

10. Modulus of Elasticity

For specimen number 1:

$$E = 2.927 \text{ M.}$$

$$\nu = 0.2825 \text{ M.}$$

$$f = 0.1212 \text{ M.}$$

$$\text{At } \nu = 0: E^0 = 1.22$$

$$E^1 = 1.21$$

$$\text{At } \nu = 0.2825 \text{ M. } E^2 = 1.09$$

$$E^3 = 0.80$$

$$\sigma = \frac{P}{b \cdot t} = \frac{2.16}{(0.8435)(0.1572)} = 16.28 \text{ k.s.i.}$$

$$\epsilon_1 = \frac{1.55 - 1.09}{1051} = 437.5 \text{ microinches/inch}$$

$$\epsilon_2 = \frac{1.51 - 0.86}{1040} = 625 \text{ microinches/inch}$$

$$\epsilon = \frac{\epsilon_1 + \epsilon_2}{2} = 531 \text{ microinches/inch}$$

From a composite plot of all three specimens

$$E = \frac{\Delta \sigma}{\Delta \epsilon} = \frac{40.0}{1415 \times 10^{-6}} = 28,300 \text{ k.s.i.}$$

$$v = \frac{f}{\lambda} = \frac{5.1 \times 10^8}{1.0 \times 10^{-6}} = 5.1 \times 10^{14} \text{ m/s}$$

$$v_1 = \frac{f_1}{\lambda_1} = \frac{5.1 \times 10^8}{1.0 \times 10^{-6}} = 5.1 \times 10^{14} \text{ m/s}$$

$$v_2 = \frac{f_2}{\lambda_2} = \frac{5.1 \times 10^8}{1.0 \times 10^{-6}} = 5.1 \times 10^{14} \text{ m/s}$$

$$v_3 = \frac{f_3}{\lambda_3} = \frac{5.1 \times 10^8}{1.0 \times 10^{-6}} = 5.1 \times 10^{14} \text{ m/s}$$

From a composite list of all three specimens

$$E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3.0 \times 10^8}{1.0 \times 10^{-6}} = 1.98 \times 10^{-19} \text{ J}$$

E. SUPPLEMENTARY DISCUSSION

1. Comparison of Methods for Determining σ_{cr}

The "top-of-the-knee" method gives values which are lower than the theoretical buckling stresses and are also the lowest given by any experimental analysis except for the strain-reversal method which was not usable in this case. This is in line with previous experience that this method gives low values whenever there is appreciable initial unfairness. To obtain better results it is necessary to apply the method to a series of plots for plates of the same size but having different initial deflections. If a line is then drawn through the tangent intersections and extrapolated to the σ -axis, the intercept represents the critical stress for a plate of zero initial deflection. This method was not usable for the series of plates tested in this work since there appeared to be no well-defined line through the points. A further difficulty in using the "top-of-the-knee" method is that a large number of points must be taken around the buckling point, and even then the upper tangent may be somewhat difficult to draw.

This same difficulty is inherent in Yoshiki's method, although the difficulty of drawing the tangent is reduced if a sufficient number of points are taken, and the knee appears sharper.

The Southwell method [48] and Donnell's variation [18] are based upon column theory rather than plate theory. However, these methods can be applied to some plate situations, especially when the aspect ratio is small and the $\frac{a}{t}$ ratio is large as is true for this case. For other plates these methods may be invalid, but the fact that the plots are straight lines for the present tests is strong evidence that the results are good.

I. Comparison of Methods for Determining γ

The "top-of-the-hump" method gives values which are lower than the theoretical limiting processes and are also the lowest given by any experimental analysis except for the strain-reversal method which was not usable in this case. This is in line with previous experience that this method gives low values whenever there is appreciable initial uniaxiality. To obtain better results it is necessary to apply the method to a series of plates for plates of the same size but having different initial deformations. It is also then drawn through the tangent intersections and extrapolated to the γ -axis, the intersection points the critical stress for a plate of zero initial deformation. This method was not usable for the series of plates tested in this work since there appeared to be no well-defined line through the points. Further difficulty in using the "top-of-the-hump" method is that a large number of points must be taken around the limiting point, and even when the upper tangent may be somewhat difficult to draw.

This same difficulty is inherent in Fowell's method, although the difficulty of drawing the tangent is reduced in a well-defined manner. Points are taken, and the lines appear straight.

The rotational method [15] and Fowell's method [16] are those upon column theory rather than plate theory. However, some evidence can be applied to some plate situations, especially when the ratio is small and the $\frac{1}{2}$ ratio is large as it was for this work. For small plates these methods may be invalid, but the fact that the plates are straight lines for the present seems to suggest evidence that the results are good.

In any event, either method may be helpful in that additional points can be taken from the straight line plot and used to more fully define the σ -d curve when the "top-of-the-knee" or Yoshiki's method is used. Donnell's method seems somewhat preferable when it can be used since the plotted points are evenly spaced (for even increments of load) and since the critical load can be read directly as the intercept on the P-axis.

2. Deflection Measurements

During the tests numerous lateral deflection measurements were made along the plate, using the planed edge of the angle connecting the "a"-edge supports as the reference line. These proved to be practically useless, since the plate adjusted itself in the early stages of loading, and the deflections for the lower loads did not reflect bending in the plate. Attempts to use these values when making buckling analyses generally failed.

A far better measurement of the lateral deflections in the plate was the difference of the strains in opposite pairs of gages. These differences are directly proportional to the moment, and when the deformation of the plate is sinusoidal, they are proportional to the lateral deflection. These values are free of the effects of any lateral movement (without bending) which might occur as the plate adjusts itself to fit in the grooves in the loading bar. Furthermore, these readings do not reflect residual stresses which may be present in the plate.

Initial deflections were measured at various points on the four plates prior to placing them in the test apparatus. This was accomplished by laying a straight edge across the short dimension of the plate, and measuring the largest unfairness with a feeler gage. A plot

[illegible]

SECRET

[illegible][illegible]

1. The first of these is the fact that the Government has been unable to secure the necessary funds to carry out its policy of maintaining the value of the pound sterling at its pre-war level. This has been due to a variety of factors, including the fact that the Government has been unable to secure the necessary foreign exchange to finance its operations.

of the unfairness along the plate's horizontal centerline did not define any simple curve such as a sine curve. Thus it was impossible to consider these measurements as anything other than an indication of the approximate magnitude of equivalent unfairness. The extrapolated values of d_0 taken from the Donnell and Southwell plots compare fairly well with these measured values except for the case of Plate No. 1. (See Table IIIB). In the case of Plate No. 1, the measured values were especially dubious since it was necessary to block the plate into place prior to loading in order to make the long edges approximately straight. The extremely complex initial curvature affected not only the equivalent initial unfairness but apparently made the plate more resistant to buckling, probably since more energy was required to produce the final sinusoidal configuration.

3. Calibration of the Testing Machine

During most of the tests a 0-1000 lb. gage was connected to the upper manifold and the pressure recorded along with the other data. The gage was calibrated at several points and the results plotted. (See Fig. 35) To obtain an equivalent gage pressure as indicated by the testing machine gages, the total indicated load was divided by the total jack ram area of one set of jacks. As can be seen from Fig. 35 the difference at 20,000 lbs. indicated load on the testing machine, and integrated jack loading is about 615 lbs. Extrapolated to 30,000 lbs., the approximate range of ultimate plate loads, this difference becomes about 925 lbs.

If we analyze a free body diagram of a jack it is possible to draw some conclusions about this observed difference in readings.

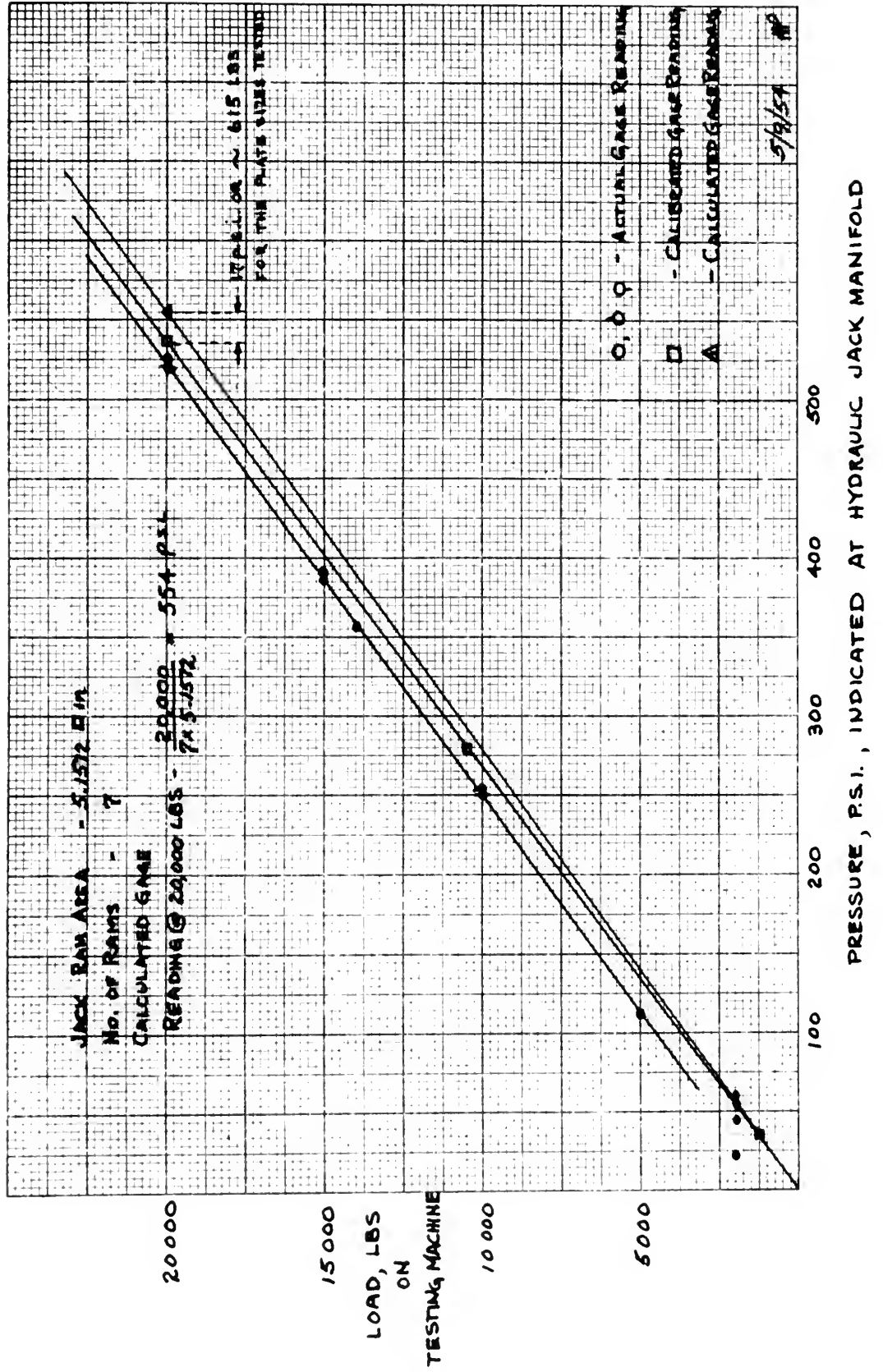
of the uniformity along the plate's horizontal centerline and not
define any simple curve such as a sine curve. There is no possibility
to consider these measurements as anything other than an indication
of the approximate magnitude of equivalent resistance. The entire
related values of d , taken from the Journal and horizontal plate were
purely fairly well with those measured when using the same of plate
No. 1. (See Table III). In the case of plate No. 1, the measured
values were especially reliable since it was necessary to place the plate
into place prior to loading in order to make the long edges approximately
if straight. The extremely complex initial curvature allowed not only
the equivalent initial uniformity but apparently none of the plate were
resistant to bending, probably since more energy was required to bend
than the final almost total configuration.

3. Evaluation of the Tension Machine

During most of the tests a 0-100 lb. force was measured in the
upper member and the pressure recorded along with the other data. The
page was utilized at several points and the results plotted. (See
Fig. 12) It shows an equivalent force pressure as indicated by the
the machine page, the total indicated load was divided by the
jack was one of one out of ten. It was the same for Fig. 13 and
differences of 20,000 lbs. indicated load on the machine machine, the
integrated jack loading is about 600 lbs. The difference is 20,000 lbs.
the approximate range of distance of the load, but the difference is only
about 200 lbs.

If we analyze a free body diagram of a part in its rest it is
then some conclusions about this aspect of the machine in bending.

FIG. 35
CALIBRATION OF TESTING MACHINE



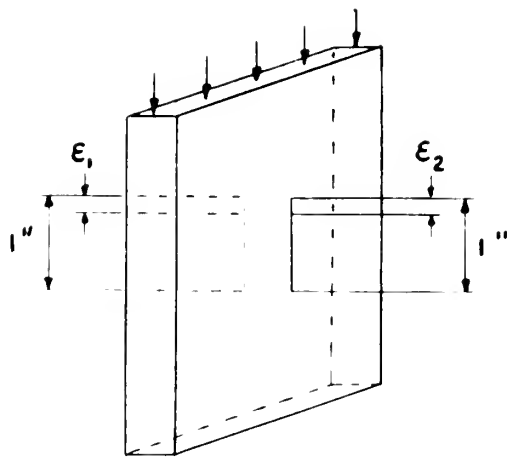
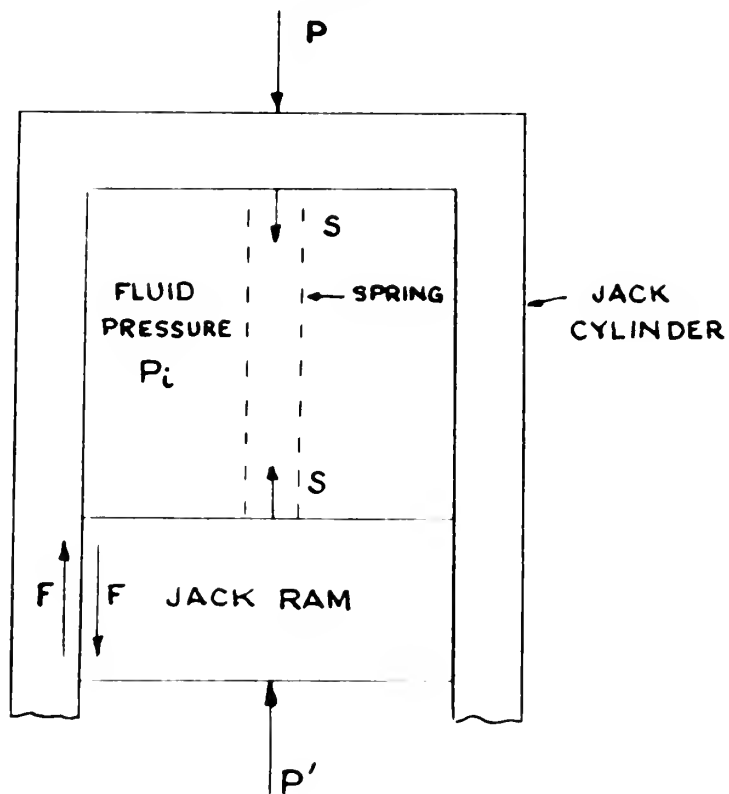


FIG. 36



FREE BODY DIAGRAM
FORCES ON A HYDRAULIC
JACK

From Fig. 36 we can write the following equations:

$$P = P_1 A_j - S + F \quad (12)$$

$$P' = P_1 A_j - S + F \quad (13)$$

where

P = total load on I-beam, (lbs.)

P' = total load on edge of test plate, (lbs.)

P_1 = jack internal hydraulic pressure, (psi)

A_j = total piston area of seven jacks, (sq. in.)

S = total return spring force of seven jacks, (lbs.)

F = total friction force between jack rams and jack cylinders (lbs.)

Under the conditions which prevailed when gage readings were taken the rams could move only inward since the hand pump was not in use. Hence, the direction of the friction force, F , is known.

From equations (12) and (13) we have:

$$P = P' \quad \text{and}$$

$$P - P_1 A_j = F - S$$

Unfortunately the pressure gage attached to the jack manifold was not sensitive enough at or near zero readings to give a value for S at different jack extensions.

The results indicate however that if the testing machine gage is a true measure of the load, P ,

$$\begin{aligned} P &> P_1 A_j && \text{or} \\ P - P_1 A_j &> 0 && \text{hence} \\ F - S &> 0 && \text{or} \\ F &> S \end{aligned}$$

This result is absurd when $P_1 \approx 0$ since the spring force does indeed overcome jack friction and return the rams to the initial position.

From Fig. 10 we can write the following equations:

$$P = P_1 A_j - S + F \quad (12)$$

$$P_1 = P_1 A_j - S + F \quad (13)$$

where

P = total load on I-beam, (lbs.)

P_1 = total load on edge of test piece, (lbs.)

P_1 = jack internal hydraulic pressure, (psi)

A_j = total piston area of seven jacks, (sq. in.)

S = total return spring force of seven jacks, (lbs.)

F = total friction force between jack frame and jack cylinders, (lbs.)

Under the conditions which prevailed when gage readings were taken the

rams could move only inward since the hand pump was not in use. Hence,

the direction of the friction force, F , is inward.

From equations (12) and (13) we have:

$$P = P_1 \quad \text{and}$$

$$P = P_1 A_j - S + F$$

Unfortunately the pressure gage attached to the jack manifold was

not sensitive enough at or near zero readings to give a value for

at different jack extensions.

The results indicate however that if the testing machine gage is

a true measure of the load, P ,

$$P > P_1 A_j$$

$$P = P_1 A_j > 0$$

$$P < 0$$

$$P < 0$$

This result is absurd when $P = 0$ since the spring force does indeed

overcome jack friction and return the rams to the initial position.

The validity of this inequality when P_1 is large, cannot be judged accurately from the known data. However, the analysis shows that the observations of Fig. 35 are possible, i.e., that the testing machine gage readings may be correct, but the results also cast reasonable doubt on this assumption. On this basis the authors requested that the gages of machine No. 105 be calibrated at least at one load, 20,000 lbs. It was found that the last calibration test was performed in April, 1950. Unfortunately the calibration was not completed in time for inclusion in this thesis but such a confirmation should be made prior to future buckling tests.

the validity of this hypothesis when it is found, however, to be
inadequately from the known data. However, the analysis shows that
the observations of 1920 are possible, i.e., that the existing
machine age readings may be correct, but the results also show that
some doubt on this assumption. On this basis the authors con-
sidered that the pages of machine No. 105 be eliminated at least as
one load, 20,000 lbs. It was found that the last calibration test
was performed in April, 1920. Unfortunately the calibration was not
completed in time for inclusion in this thesis but such a confirmation
should be made prior to future loading tests.

F. DETERMINATION OF YOUNG'S MODULUS

To determine the modulus of elasticity of the test specimens in compression, a compression jig using the single plate method described and built by Polychrone [40] was used.

Briefly the jig consists of a frame which holds the guide plates and specimen in place and contains a subpress in the form of a plunger which bears on the specimen. The steel guide plates are milled with triangular grooves which run the length of the specimen. The grooves opposite each other in the guide plates are staggered so that lateral extension of the specimen is permitted when a load is applied. Two Huggenberger strain gages of one inch base length are attached to opposite edges of the specimen through apertures in the frame. Guide plate pressure and centering is accomplished by adjusting two $3/8$ " knurled screws until they are just hand tight.

The specimens were rough cut from the same plate and in the same direction as were the test plates. Test plates and compression specimens received the same surface preparation such as sand- or shot-blasting or pickling.

Three specimens were prepared and milled to the final dimensions. The thickness was determined in the same manner as that described for the test plates. All specimens were of the same length and width, $0.8435" \times 2.547"$ which conform to the ASTM standards of a 1 to 3 proportion. (Designation E9-33T) The results of the three tests are given in Fig. 37. There are several possible sources of error in this procedure. The grooved guide plates do not permit complete freedom of lateral extension. This has effect primarily on the determination of the

to determine the nature of the reaction of the polymer with the reagent. The reaction of the polymer with the reagent was studied by means of the following experiment:

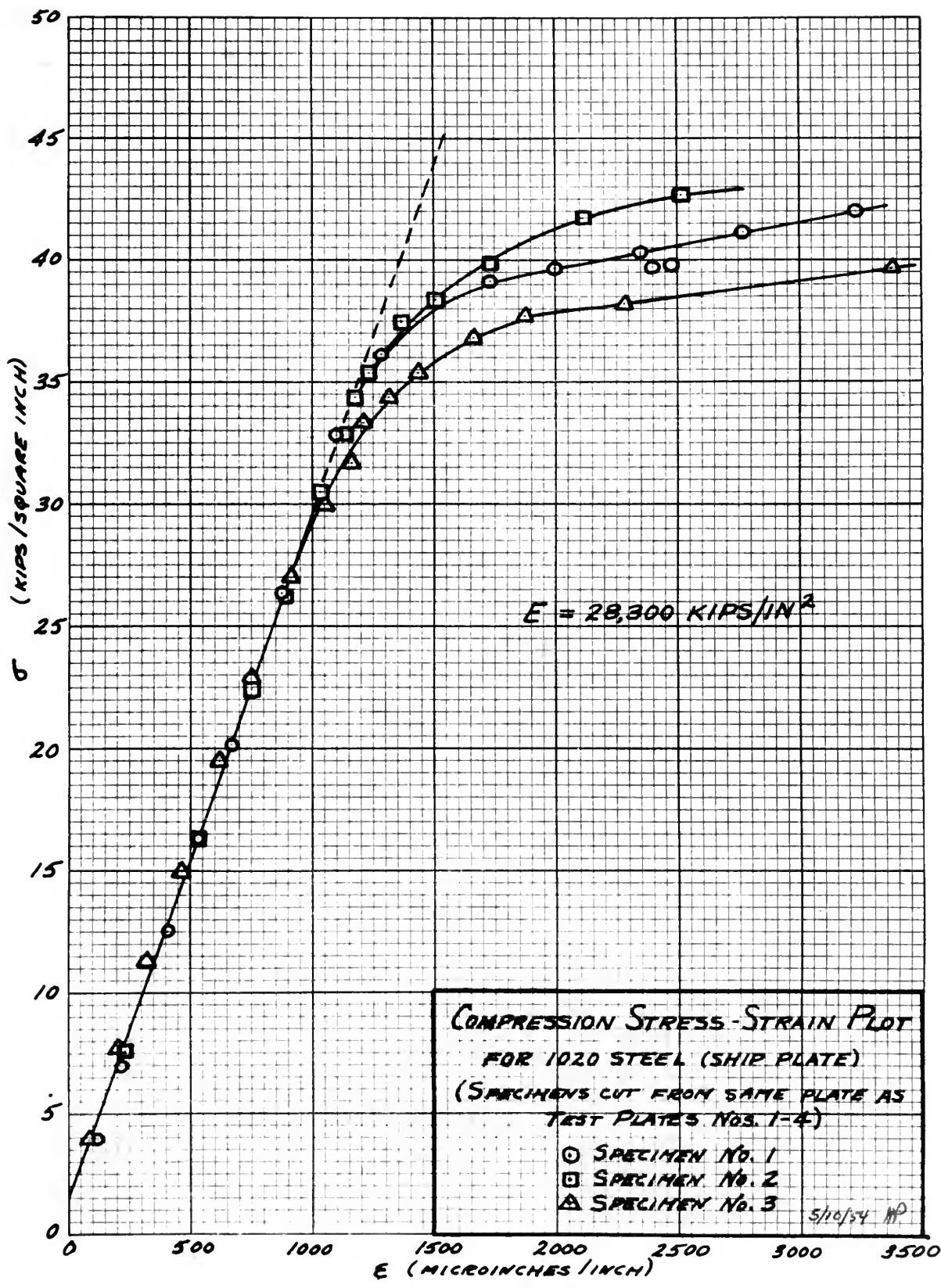
Initially the big mistake of a lawyer is to believe the words of the
and specimen in place and therefore a specimen in the form of a large
which I saw on the specimen. The great mistake is to believe that
evidence is given when you are looking at the specimen. The great
opposite each other in the field and the other is that the
evidence of the specimen is not the same as the evidence of the field.

1. The first group of specimens is composed of the following:

1. The first of the main points made in the report is that the
2. Commission has not been able to establish any connection between
3. the activities of the various groups and the activities of the
4. various individuals mentioned in the report. The Commission has
5. found that the various groups are not connected with each other
6. and that the various individuals mentioned in the report are not
7. connected with each other. The Commission has found that the
8. various groups are not connected with each other and that the
9. various individuals mentioned in the report are not connected
10. with each other. The Commission has found that the various
11. groups are not connected with each other and that the various
12. individuals mentioned in the report are not connected with each
13. other. The Commission has found that the various groups are not
14. connected with each other and that the various individuals
15. mentioned in the report are not connected with each other.

[illegible]

1. The first of these is the fact that the majority of the population of the United States is now living in urban areas. This is a result of the process of urbanization, which has been going on since the beginning of the 20th century. The process of urbanization is the movement of people from rural areas to urban areas. This movement is caused by a number of factors, including the search for better living conditions, the desire for education, and the need for employment. The process of urbanization has led to the growth of large cities and the decline of small towns and villages. This has had a significant impact on the economy and society as a whole. The majority of the population now lives in urban areas, which are characterized by high population density, a high level of economic activity, and a high level of social organization. This has led to the development of a new type of society, which is based on the city. The city is now the center of economic and social life in the United States. The majority of the population now lives in urban areas, which are characterized by high population density, a high level of economic activity, and a high level of social organization. This has led to the development of a new type of society, which is based on the city. The city is now the center of economic and social life in the United States.



yield point. There is a friction force developed between the specimen and its guide plates and also between the plunger and its guides, particularly if the loading should be uneven. Since the surface of these specimens was quite rough, care was taken not to tighten the knurled screws excessively especially since the prime result expected was the modulus rather than an accurate yield point. It should be noted however that such a friction force would tend to raise the value of E . Since the value of E found was slightly below that which one would normally expect for the type of steel tested, it is probable that the effect of such friction was not large and was reasonably constant for all tests.

The variations occurring in the stress-strain curve above the proportional limit are probably caused by unevenness in the load distribution across the loaded edge of the specimen. If one side was loaded more heavily than the other, the strain on that side would reach the proportioned limit before the other side and cause the curve to become more linear at various loads depending on the degree of unevenness. The points recorded above its proportioned limit were recorded after reasonable yielding had taken place but no attempt was made to wait until final values of the load and its strain were recorded. For this particular study an accurate value of the yield point is not necessary. It was felt that there was no need to pursue this phenomenon further. It is believed, however, in the future development of this test program, an accurate value of the yield stress will become important to the analysis of the data. Hence, the reasons for these variations should be pursued.

yield point. There is a distinct force exerted by the
and the guide rollers and also between the rollers and the
theoretically if the rollers should be perfect. However, in practice, some
spacings was quite large, some was taken not so close and the rollers
surface excessively irregularly along the entire length. The rollers were in
condition rather than an accurate yield point. The rollers were in
even that such a condition would tend to make the rollers
since the rollers in the first was difficult to make and the rollers
normally expect for the type of steel tested. It is possible that
effect of such rollers was not large and was reasonably close to the
test.

[illegible]

Specifications of Compression Test Procedure

- Test Specimens:** Cut from same plate as test plates and in the same direction. Milled to 2.547 x 0.8435 inches. Three specimens tested.
- Strain Gages:** Two Type A Huggenberger - 1 inch gage length
No. 2195 Gage Factor 1051
No. 2201 Gage Factor 1041
- Testing Machine:** Testing Materials Lab. #203
Manufacturer - Riehle' Bros.
Capacity - 20,000 pounds
Specimens held in compression jig.
Spherical head used.
- Test Procedure:** Knurled bolts holding guide plates were tightened barely hand tight. Load of about 200 pounds applied and released several times to check zero readings on Huggenberger gages. Load applied in increments of approximately 500 pounds. Gages read at each step. Modulus of elasticity found by plotting stress vs. strain.

APPENDIX G

ORIGINAL DATA

APPENDIX C

ORIGINAL DATA

TABLE IV

Data Sheet

Date: 29 March 1954

Test No: 2

Plate No.: 1

Strain Indicator

Serial No. D58130

Type K

G.F. Setting 2.01

E-Edge Conditions

Load Application - Machine
Jacks

Bar - 3/4" (Grooved)

Gasket - Neoprene

No Segments
No Shims

| Load Zero
(kips) | 2 | 4 | 6 | 8 | 10 | 12 | 14 | Final
Zero |
|---------------------|--|------|------|------|------|------|------|---------------|
| Gage | Strain Indicator Readings (microinches/inch) | | | | | | | |
| 1 | 8-608 | 592 | 589 | 589 | 582 | 574 | 568 | 564 |
| 2 | 7-177 | 155 | 158 | 152 | 150 | 145 | 141 | 136 |
| 3 | 9-249 | 210 | 205 | 200 | 197 | 190 | 187 | 180 |
| 4 | 4-407 | 401 | 395 | 385 | 376 | 363 | 357 | 343 |
| 5 | 8-752 | 738 | 738 | 725 | 721 | 711 | 708 | 707 |
| 6 | 7-737 | 730 | 728 | 720 | 718 | 710 | 708 | 691 |
| 7 | 6-782 | 788 | 792 | 783 | 770 | 749 | 721 | 691 |
| 8 | 5-557 | 535 | 531 | 538 | 542 | 552 | 570 | 582 |
| 9 | 7-179 | 191 | 184 | 171 | 152 | 141 | 128 | 107 |
| 10 | 8-866 | 821 | 810 | 800 | 795 | 790 | 791 | 792 |
| 11 | 6-651 | 666 | 664 | 662 | 662 | 659 | 660 | 657 |
| 12 | 6-1017 | 972 | 966 | 960 | 952 | 944 | 940 | 930 |
| 13 | 8-873 | 850 | 847 | 841 | 840 | 836 | 836 | 833 |
| 14 | 9-267 | 261 | 250 | 240 | 230 | 220 | 208 | 193 |
| 15 | 7-423 | 380 | 380 | 376 | 372 | 367 | 365 | 361 |
| 16 | 7-907 | 1067 | 1077 | 1071 | 1069 | 1061 | 1058 | 1050 |
| 17 | 8-830 | 797 | 798 | 791 | 790 | 787 | 787 | 783 |
| 18 | 9-242 | 272 | 269 | 264 | 260 | 250 | 241 | 230 |
| 19 | 6-1000 | 970 | 962 | 957 | 953 | 948 | 950 | 947 |
| 20 | 7-714 | 740 | 732 | 720 | 710 | 694 | 682 | 668 |
| 21 | 9-121 | 090 | 079 | 071 | 067 | 059 | 054 | 053 |
| 22 | 8-200 | 220 | 210 | 201 | 190 | 178 | 168 | 148 |
| 23 | 7-1060 | 1022 | 1013 | 1008 | 1002 | 996 | 992 | 992 |
| 24 | 8-411 | 426 | 418 | 408 | 400 | 390 | 382 | 367 |
| 25 | 8-936 | 891 | 887 | 880 | 875 | 868 | 863 | 856 |
| 26 | 8-341 | 347 | 332 | 320 | 310 | 297 | 287 | 273 |
| 27 | 6-850 | 790 | 780 | 768 | 760 | 751 | 749 | 745 |
| 28 | 7-911 | 920 | 913 | 902 | 894 | 882 | 870 | 857 |
| 29 | 7-198 | 161 | 157 | 148 | 141 | 134 | 128 | 121 |
| 30 | 7-762 | 765 | 762 | 758 | 755 | 750 | 747 | 738 |
| 31 | 7-460 | 454 | 450 | 447 | 441 | 435 | 430 | 420 |
| 32 | 8-117 | 095 | 091 | 088 | 087 | 081 | 082 | 080 |
| 33 | 8-651 | 655 | 641 | 629 | 617 | 600 | 580 | 557 |
| 34 | 5-985 | 952 | 952 | 947 | 945 | 944 | 949 | 953 |
| 35 | 4-750 | 758 | 738 | 722 | 705 | 679 | 644 | 595 |
| 36 | 6-1030 | 1010 | 1026 | 1034 | 1047 | 1061 | 1090 | 1130 |

061824

000000 - Nooprene
Bar - 3/4" (Grooved)
Lecithin

2. The United States of
 America

PI 11143

[illegible]

TABLE IV

Data Sheet

Date: 29 March 1954

Test No.: 2 (contd.)

Plate No.: 1

Strain Indicator

Serial No. 058130

Type K

O.F. Setting 2.01

B-Edge Conditions

Load Application - Machine
Jacks

Bar - 3/4" (Grooved)

Gasket - Neoprene

No Segments

No Shims

| Load
(kips) | Zero | 2 | 4 | 6 | 8 | 10 | 12 | 14 | Final
Zero |
|----------------|--|-----|-----|-----|-----|-----|-----|-----|---------------|
| Gage | Strain Indicator Readings (microinches/inch) | | | | | | | | |
| 37 | 6-521 | 510 | 524 | 534 | 548 | 557 | 573 | 570 | 525 |
| 38 | 7-479 | 461 | 448 | 428 | 407 | 380 | 348 | 334 | 480 |
| 39 | 8-463 | 457 | 458 | 460 | 466 | 470 | 472 | 475 | 466 |
| 40 | 8-457 | 439 | 429 | 413 | 400 | 381 | 365 | 351 | 459 |
| 41 | 8-1000 | 988 | 980 | 970 | 968 | 964 | 960 | 952 | 1007 |
| 42 | 8-952 | 937 | 923 | 910 | 900 | 891 | 882 | 880 | 958 |
| 43 | 8-258 | 241 | 232 | 218 | 202 | 182 | 162 | 143 | 263 |
| 44 | 7-557 | 563 | 561 | 564 | 571 | 578 | 587 | 591 | 560 |
| 45 | 8-173 | 151 | 142 | 130 | 119 | 103 | 090 | 071 | 180 |
| 46 | 7-719 | 740 | 747 | 747 | 750 | 751 | 758 | 760 | 725 |
| 47 | 8-748 | 724 | 711 | 698 | 683 | 667 | 649 | 630 | 755 |
| 48 | 7-046 | 076 | 083 | 088 | 092 | 096 | 100 | 105 | 051 |
| 49 | 7-410 | 380 | 367 | 349 | 330 | 310 | 290 | 269 | 416 |
| 50 | 7-248 | 272 | 276 | 280 | 288 | 296 | 308 | 316 | 252 |
| 51 | 7-540 | 521 | 513 | 504 | 498 | 487 | 475 | 462 | 548 |
| 52 | 4-820 | 838 | 841 | 842 | 843 | 842 | 844 | 846 | 826 |
| 53 | 6-390 | 367 | 358 | 329 | 312 | 295 | 278 | 255 | 398 |
| 54 | 7-377 | 376 | 460 | 438 | 370 | - | 336 | 335 | 352 |
| 55 | 7-828 | 794 | 770 | 740 | 710 | 674 | 639 | 604 | 838 |
| 56 | 8-223 | 243 | 252 | 259 | 271 | 286 | 302 | 318 | 228 |
| 57 | 8-978 | 920 | 906 | 890 | 876 | 858 | 840 | 820 | 983 |
| 58 | 6-410 | 430 | 436 | 438 | 444 | 450 | 459 | 465 | 411 |
| 59 | 7-1020 | 962 | 960 | 935 | 920 | 900 | 880 | 856 | 1028 |
| 60 | 8-477 | 507 | 511 | 517 | 521 | 524 | 528 | 530 | 480 |
| 61 | 7-554 | 514 | 503 | 488 | 470 | 453 | 438 | 419 | 561 |
| 62 | 5-670 | 686 | 682 | 680 | 682 | 682 | 684 | 688 | 675 |
| 63 | 8-661 | 637 | 638 | 630 | 625 | 621 | 623 | 620 | 667 |
| 64 | 8-333 | 341 | 330 | 323 | 317 | 305 | 289 | 282 | 339 |

Deflection Readings at 14 kips Load
(from a reference line)

| Gage Position | Reading |
|---------------|----------------|
| 1 | 0.3832--0.0020 |
| 2 | 0.3915--0.0015 |
| 3 | 0.2920--0.0060 |

TABLE V

Data Sheet

Date: 31 March 1954

Test No.: 5

Plate No.: 1

Strain Indicator

Serial No. D58130

Type K

G.F. Setting 2.01

B-Edge Conditions

Load Application - Machine

Jacks

Bar - 3/4" (Flat)

Gasket - Single Solder 3/32" diam. (new)

No Segments

No Shims

| Load | 2 | 20 | Zero | 10 | 20 | Gage | Zero | 10 | 20 |
|--------|------------|-------|---|------|------|------|--------|------|------|
| (kips) | | | | | | | | | |
| Pi | 60 | 520 | 0 | 250 | 520 | | 0 | 250 | 520 |
| Gage | d (inches) | | Strain Indicator Reading (microinches/inch) | | | | | | |
| 7 | .315* | .325* | 6-803 | 660 | 521 | 37 | 6-520 | 674 | 705 |
| 8 | | | 5-536 | 561 | 620 | 38 | 7-467 | 240 | 150 |
| 9 | .318 | .335 | 7-200 | 214 | 105 | 39 | 8-460 | 447 | 429 |
| 10 | | | 8-861 | 870 | 818 | 40 | 8-454 | 392 | 323 |
| 11 | .322 | .356 | 6-646 | 610 | 644 | 41 | 8-1002 | 977 | 979 |
| 12 | | | 6-1020 | 977 | 878 | 42 | 8-957 | 912 | 867 |
| 13 | .341 | .400 | 8-872 | 846 | 851 | 43 | 7-1262 | 1206 | 1207 |
| 14 | | | 9-269 | 249 | 187 | 44 | 7-560 | 559 | 508 |
| 15 | .362 | .435 | - | - | - | 45 | 7-1180 | 1139 | 1120 |
| 16 | | | - | - | - | 46 | 7-720 | 720 | 663 |
| 17 | .360 | .434 | 8-832 | 881 | 932 | 47 | 8-748 | 715 | 666 |
| 18 | | | 8-1240 | 1144 | 1016 | 48 | 6-1051 | 1014 | 980 |
| 19 | .350 | .420 | 6-1000 | 1051 | 1092 | 49 | 7-414 | 420 | 430 |
| 20 | | | 7-710 | 562 | 429 | 50 | 6-1249 | 1186 | 1142 |
| 21 | .319 | .375 | - | - | - | 51 | 7-544 | 498 | 490 |
| 22 | | | - | - | - | 52 | 4-815 | 791 | 749 |
| 23 | .307 | .318 | 7-1060 | 975 | 994 | 53 | 6-397 | 321 | 267 |
| 24 | | | 8-402 | 418 | 316 | 54 | 7-343 | 340 | 302 |
| 25 | .292 | .257 | 8-930 | 869 | 834 | 55 | 7-837 | 753 | 711 |
| 26 | | | 8-333 | 341 | 278 | 56 | 8-212 | 218 | 198 |
| 27 | .267 | .265 | 6-848 | 774 | 718 | 57 | 8-987 | 908 | 830 |
| 28 | | | 7-903 | 890 | 850 | 58 | 6-384 | 398 | 411 |
| 29 | .237 | .223 | 6-1198 | 1140 | 1110 | 59 | 7-1021 | 827 | 681 |
| 30 | | | 7-753 | 733 | 673 | 60 | 8-473 | 569 | 609 |
| 31 | .211 | .194 | 7-457 | 370 | 309 | 61 | 7-558 | 426 | 313 |
| 32 | | | 7-1112 | 1107 | 1009 | 62 | 5-666 | 733 | 776 |
| 33 | .219 | .198 | 8-650 | 586 | 504 | | | | |
| 34 | | | 5-971 | 977 | 997 | | | | |
| 35 | .231* | .225* | 4-773 | 495 | 152 | | | | |
| 36 | | | 6-990 | 1180 | 1140 | | | | |

* Readings taken between gage positions 7 & 9 or 33 & 35

Gage pairs 15, 16; 21, 22; 63, 64; 65, 66 - no readings

1954年 5月22日

DATE: 12-11-68

1000

SECRET

22-11-1961

061638 07 19 1968

1975

10.3 10.3 10.3

| Line | Time | Lat | Long | Alt | Dist | Dir | Wind | Temp | Hum | Pres | Cloud | Vis | Sea | Remarks |
|------|------|-------|--------|------|------|-----|------|------|-----|------|-------|-----|-----|---------|
| 1 | 0000 | 34-00 | 122-00 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 2 | 0005 | 34-05 | 122-05 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 3 | 0010 | 34-10 | 122-10 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 4 | 0015 | 34-15 | 122-15 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 5 | 0020 | 34-20 | 122-20 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 6 | 0025 | 34-25 | 122-25 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 7 | 0030 | 34-30 | 122-30 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 8 | 0035 | 34-35 | 122-35 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 9 | 0040 | 34-40 | 122-40 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 10 | 0045 | 34-45 | 122-45 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 11 | 0050 | 34-50 | 122-50 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 12 | 0055 | 34-55 | 122-55 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 13 | 0100 | 35-00 | 123-00 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 14 | 0105 | 35-05 | 123-05 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 15 | 0110 | 35-10 | 123-10 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 16 | 0115 | 35-15 | 123-15 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 17 | 0120 | 35-20 | 123-20 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 18 | 0125 | 35-25 | 123-25 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 19 | 0130 | 35-30 | 123-30 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 20 | 0135 | 35-35 | 123-35 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 21 | 0140 | 35-40 | 123-40 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 22 | 0145 | 35-45 | 123-45 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 23 | 0150 | 35-50 | 123-50 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 24 | 0155 | 35-55 | 123-55 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 25 | 0200 | 36-00 | 124-00 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 26 | 0205 | 36-05 | 124-05 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 27 | 0210 | 36-10 | 124-10 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 28 | 0215 | 36-15 | 124-15 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 29 | 0220 | 36-20 | 124-20 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 30 | 0225 | 36-25 | 124-25 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 31 | 0230 | 36-30 | 124-30 | 1000 | 0.0 | 000 | 000 | 50 | 100 | 30.0 | 000 | 10 | 0 | Clear |
| 32 | 0235 | 36-35 | 124-35 | 1000 | 0.0 | 000 | 000 | | | | | | | |

[Illegible text]

Signature: _____

TABLE VI

Data Sheet

Date: 11 April 1954

B-Edge Condition

Test No.: 12

Plate No.: 1

Strain Indicator

Load Application - Pump

Segments

Jacks

Shims

Serial No. D58130

Bar - 1/8"

Type K

Gasket: Double Solder 1/16" diam. ()

G.F. Setting 2.01

Remarks: Plate reversed on a diagonal

| Load | 20 | Zero | 2 | 10 | 20 | Gage | Zero | 2 | 10 | 20 |
|--------|---------|---|------|------|------|------|--------|------|------|------|
| (kips) | | | | | | | | | | |
| Gage | d (in.) | Strain Indicator Reading (microinches/inch) | | | | | | | | |
| 7 | .196* | 6-793 | 767 | 789 | 774 | 37 | 6-502 | 504 | 540 | 597 |
| 8 | | 5-540 | 553 | 533 | 534 | 38 | 7-464 | 452 | 399 | 334 |
| 9 | .115 | 7-302 | 276 | 264 | 247 | 39 | 8-447 | 450 | 463 | 481 |
| 10 | | 8-827 | 821 | 773 | 729 | 40 | 8-435 | 402 | 341 | 260 |
| 11 | .096 | 6-641 | 636 | 648 | 670 | 41 | 8-990 | 991 | 997 | 1011 |
| 12 | | 6-1022 | 1007 | 983 | 948 | 42 | 8-945 | 937 | 912 | 889 |
| 13 | .089 | 8-861 | 848 | 851 | 872 | 43 | 8-242 | 230 | 230 | 238 |
| 14 | | 9-264 | 245 | 190 | 114 | 44 | 7-561 | 549 | 497 | 440 |
| 15 | .102 | 7-411 | 403 | 420 | 457 | 45 | 7-1163 | 1159 | 1160 | 1181 |
| 16 | | 7-900 | 907 | 876 | 841 | 46 | 7-726 | 724 | 710 | 685 |
| 17 | .137 | 8-815 | 795 | 797 | 819 | 47 | 8-730 | 719 | 699 | 696 |
| 18 | | 8-1251 | 1238 | 1190 | 1119 | 48 | 6-1061 | 1046 | 1003 | 958 |
| 19 | .172 | 6-990 | 978 | 990 | 1025 | 49 | 7-390 | 382 | 373 | 379 |
| 20 | | 7-723 | 720 | 704 | 674 | 50 | 7-254 | 254 | 246 | 234 |
| 21 | .210 | 8-1103 | 1088 | 1085 | 1098 | 51 | 7-520 | 490 | 455 | 430 |
| 22 | | 7-582 | 578 | 531 | 465 | 52 | 4-816 | 820 | 793 | 756 |
| 23 | .276 | 7-1041 | 1034 | 1040 | 1059 | 53 | 6-375 | 367 | 352 | 349 |
| 24 | | 8-402 | 403 | 389 | 361 | 54 | 7-340 | 344 | 337 | 330 |
| 25 | .298 | 8-916 | 898 | 887 | 879 | 55 | 7-809 | 796 | 757 | 718 |
| 26 | | 8-334 | 325 | 289 | 236 | 56 | 7-1204 | 1191 | 1166 | 1141 |
| 27 | .302 | 6-831 | 835 | 832 | 839 | 57 | 8-960 | 960 | 944 | 930 |
| 28 | | 7-895 | 881 | 872 | 858 | 58 | 6-367 | 360 | 352 | 351 |
| 29 | .266 | 6-1184 | 1185 | 1159 | 1135 | 59 | 7-994 | 988 | 948 | 902 |
| 30 | | 7-744 | 720 | 700 | 670 | 60 | 8-453 | 439 | 418 | 395 |
| 31 | .226 | 7-447 | 445 | 451 | 454 | 61 | 7-525 | 521 | 509 | 492 |
| 32 | | 7-1099 | 1095 | 1080 | 1070 | 62 | 5-646 | 647 | 647 | 652 |
| 33 | .212 | 8-630 | 611 | 645 | 644 | 63 | 8-643 | 620 | 581 | 530 |
| 34 | | 5-963 | 959 | 875 | 815 | 64 | 8-309 | 305 | 286 | 277 |
| 35 | .207* | 4-683 | 669 | 716 | 740 | 65 | 7-705 | 711 | 699 | 682 |
| 36 | | 6-1043 | 1054 | 1000 | 974 | 66 | 7-703 | 694 | 695 | 707 |

* Readings taken between gages 7 & 9 or 33 & 35

2000 2001

1902-1903 415-2

1945 12 11 1945

1000

1. 03 03.19

205-01201 5/10/72

061829 001 50-702



0.8 10.0 1.0

...and the

Large in a no. containers at all - unknown.

WATER - containing local

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25

...and the value of the ...

Large in a no. containers at all - unknown.

[illegible][illegible]

TABLE VII

Data Sheet

Date: 12 April 1954

B-Edge Condition

Test No.: 14

Plate No.: 1

Strain Indicator

Serial No. D50130

Type K

O.F. Setting 2.01

Load Application - Pump
Jacks

Bar - 3/4" (Flat)

Gasket - Double Solder 1/16" diam. (new)

Remark: Repeatability Run

Segments
Shims

| Load | Zero | 2 | 10 | 20 | Gage | Zero | 2 | 10 | 20 | 20 |
|--------|---|------|------|------|------|--------|------|------|------|------------|
| (kips) | | | | | | | | | | |
| Gage | Strain Indicator Reading (microinches/inch) | | | | | | | | | d (inches) |
| 7 | 6-814 | 783 | 765 | 670 | 37 | 6-520 | 528 | 588 | 618 | .193* |
| 8 | 5-553 | 541 | 524 | 570 | 38 | 7-477 | 464 | 376 | 278 | |
| 9 | 7-315 | 303 | 283 | 240 | 39 | 8-462 | 470 | 467 | 469 | .199 |
| 10 | 8-843 | 837 | 814 | 727 | 40 | 8-457 | 450 | 396 | 322 | |
| 11 | 6-650 | 649 | 648 | 639 | 41 | 8-1005 | 1012 | 986 | 972 | .213 |
| 12 | 6-1024 | 1019 | 971 | 907 | 42 | 8-963 | 940 | 890 | 813 | |
| 13 | 8-871 | 873 | 862 | 877 | 43 | 8-1263 | 260 | 242 | 232 | .257 |
| 14 | 9-278 | 260 | 180 | 090 | 44 | 7-578 | 557 | 520 | 455 | |
| 15 | 7-424 | 419 | 427 | 468 | 45 | 7-1179 | 1172 | 1160 | 1167 | .286 |
| 16 | 7-908 | 891 | 844 | 760 | 46 | 7-743 | 719 | 681 | 626 | |
| 17 | 8-829 | 828 | 816 | 823 | 47 | 8-747 | 747 | 728 | 718 | .283 |
| 18 | 8-1262 | 1260 | 1207 | 1110 | 48 | 6-1078 | 1071 | 1040 | 997 | |
| 19 | 6-1003 | 997 | 990 | 1019 | 49 | 7-409 | 396 | 362 | 340 | .262 |
| 20 | 7-732 | 727 | 667 | 582 | 50 | 7-268 | 260 | 221 | 158 | |
| 21 | 8-1120 | 1110 | 1102 | 1118 | 51 | 7-539 | 531 | 491 | 459 | .208 |
| 22 | 7-594 | 583 | 532 | 450 | 52 | 4-840 | 837 | 814 | 774 | |
| 23 | 7-1050 | 1050 | 1047 | 1064 | 53 | 6-390 | 368 | 312 | 249 | .164 |
| 24 | 8-424 | 400 | 372 | 299 | 54 | 7-358 | 346 | 327 | 293 | |
| 25 | 8-928 | 913 | 883 | 868 | 55 | 7-826 | 791 | 720 | 637 | .123 |
| 26 | 8-353 | 343 | 296 | 220 | 56 | 7-1224 | 1209 | 1178 | 1136 | |
| 27 | 6-848 | 857 | 810 | 777 | 57 | 8-975 | 967 | 919 | 862 | .102 |
| 28 | 7-911 | 896 | 842 | 791 | 58 | 6-390 | 390 | 370 | 350 | |
| 29 | 6-1202 | 1205 | 1180 | 1150 | 59 | 7-1012 | 1010 | 968 | 922 | .079 |
| 30 | 7-759 | 755 | 730 | 679 | 60 | 8-471 | 469 | 460 | 443 | |
| 31 | 7-468 | 470 | 440 | 417 | 61 | 7-544 | 540 | 508 | 469 | .062 |
| 32 | 7-1110 | 1108 | 1076 | 1044 | 62 | 5-660 | 661 | 653 | 641 | |
| 33 | 8-658 | 658 | 661 | 640 | 63 | 8-663 | 640 | 569 | 492 | .141 |
| 34 | 5-967 | 963 | 900 | 841 | 64 | 8-325 | 317 | 290 | 269 | |
| 35 | 4-701 | 702 | 822 | 804 | 65 | 7-732 | 698 | 692 | 682 | .173* |
| 36 | 6-1072 | 1022 | 869 | 820 | 66 | 7-715 | 719 | 682 | 632 | |

* Readings taken between gages 37 & 39 or 63 & 65

2000 2001

1950年5月1日 星期五

REF ID: A66111

... ..

UNITED STATES DEPARTMENT OF JUSTICE
FEDERAL BUREAU OF INVESTIGATION

SECRET

500

90. 100. 110

33: 2005-2006

~~SECRET~~

(100) 100 - 100

[illegible]

中華民國二十九年九月九日

[illegible]

[Illegible text]

TABLE VIII

Data Sheet

Date: 14 April 1954

Test No.: 16

Plate No.: 1

Strain Indicator

Serial No. D58130

Type K

S.F. Setting 2.04

B-Edge Conditions

Load Application - Pump

No Jacks

Bar - 3/4" (flat)

Gasket - Double Solder

1/16" diam. (new)

Segments

Shims

| Load | Zero | 2 | 10 | 20 | Gage | Zero | 2 | 10 | 20 |
|--------|--------|------|------|------|------|--------|------|------|------|
| (kips) | | | | | | | | | |
| Gage | | | | | | | | | |
| 7 | 6-827 | 820 | 835 | 814 | 37 | 6-582 | 616 | 664 | 672 |
| 8 | 5-520 | 515 | 418 | 362 | 38 | 7-371 | 325 | 231 | 145 |
| 9 | 7-298 | 280 | 277 | 248 | 39 | 8-433 | 441 | 442 | 438 |
| 10 | 8-787- | 780 | 726 | 657 | 40 | 8-398 | 373 | 332 | 288 |
| 11 | 6-646 | 637 | 625 | 620 | 41 | 8-958 | 947 | 920 | 906 |
| 12 | 6-1002 | 992 | 952 | 892 | 42 | 8-905 | 884 | 826 | 747 |
| 13 | 8-833 | 832 | 825 | 830 | 43 | 7-1230 | 1223 | 1205 | 1198 |
| 14 | 8-1224 | 1217 | 1174 | 1119 | 44 | 7-538 | 521 | 477 | 423 |
| 15 | 7-404 | 409 | 398 | 408 | 45 | 7-1143 | 1141 | 1120 | 1121 |
| 16 | 7-870 | 861 | 798 | 725 | 46 | 7-700 | 680 | 641 | 597 |
| 17 | 8-788 | 791 | 800 | 812 | 47 | 8-701 | 690 | 670 | 660 |
| 18 | 8-1202 | 1187 | 1148 | 1080 | 48 | 6-1046 | 1033 | 998 | 948 |
| 19 | 6-988 | 981 | 970 | 971 | 49 | 7-381 | 372 | 347 | 338 |
| 20 | 7-697 | 691 | 619 | 533 | 50 | 7-234 | 230 | 203 | 171 |
| 21 | 8-1067 | 1064 | 1062 | 1071 | 51 | 7-507 | 496 | 451 | 406 |
| 22 | 7-559 | 567 | 527 | 461 | 52 | 4-842 | 835 | 811 | 787 |
| 23 | 7-1015 | 1015 | 1009 | 1007 | 53 | 6-370 | 352 | 308 | 248 |
| 24 | 8-385 | 391 | 360 | 301 | 54 | 7-333 | 331 | 310 | 278 |
| 25 | 8-867 | 864 | 838 | 792 | 55 | 7-777 | 761 | 708 | 625 |
| 26 | 8-320 | 311 | 265 | 170 | 56 | 7-1194 | 1190 | 1162 | 1134 |
| 27 | 6-813 | 807 | 778 | 745 | 57 | 8-910 | 899 | 852 | 807 |
| 28 | 7-888 | 890 | 852 | 804 | 58 | 6-384 | 377 | 366 | 360 |
| 29 | 6-1165 | 1163 | 1155 | 1144 | 59 | 7-964 | 955 | 910 | 858 |
| 30 | 7-734 | 738 | 720 | 703 | 60 | 8-436 | 433 | 422 | 419 |
| 31 | 7-430 | 424 | 392 | 361 | 61 | 7-504 | 486 | 430 | 370 |
| 32 | 7-1080 | 1079 | 1048 | 1010 | 62 | 5-662 | 670 | 665 | 675 |
| 33 | 8-601 | 617 | 588 | 562 | 63 | 8-610 | 542 | 467 | 350 |
| 34 | 5-968 | 945 | 872 | 812 | 64 | 7-1291 | 1281 | 1261 | 1260 |
| 35 | 4-711 | 800 | 842 | 807 | 65 | 7-678 | 580 | 486 | 326 |
| 36 | 6-1043 | 847 | 727 | 647 | 66 | 7-702 | 722 | 702 | 751 |

2007 2008

SECRET 100-4

Figure 2: A 3D plot showing the distribution of the number of clusters (K) for different values of the parameter α . The x-axis represents the number of clusters (K), ranging from 0 to 10. The y-axis represents the probability density function (PDF), ranging from 0 to 0.05. The z-axis represents the parameter α , ranging from 0 to 1. The plot shows that as α increases, the distribution of K becomes more concentrated around K=1.

Lead Application - (new)
No later
Bar - 1/16 (1980)
Cabinet - Dennis Golden
1/16 (1980) (new)

Date: 14 April 1961
 Time: 10:10
 Plate No.: 1
 Serial No.: 10010
 Type: X
 S. E. Section 1.00

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

TABLE IX

Data Sheet

Date: 14 April 1954
 Test No.: 16 (continued)
 Plate No.: 1
 Strain Indicator
 Serial No. D58130
 Type E
 G.F. Setting 2.04

B-Edge Conditions

Load Application - Pump
 No Jacks
 Bar - 3/4" (flat)
 Gasket - Double Solder
 1/16" diam. (new)
 Segments
 Shine

| Load
Kips | Zero | 2 | 20 |
|--------------|------------------------|-------|-------|
| Gage | Deflection - d(inches) | | |
| 37 | .185* | .190* | .184* |
| 39 | .186 | .193 | .179 |
| 41 | .189 | .207 | .181 |
| 43 | .218 | .246 | .206 |
| 45 | .247 | .284 | .235 |
| 47 | .253 | .291 | .242 |
| 49 | .252 | .280 | .235 |
| 51 | .226 | .239 | .205 |
| 53 | .219 | .226 | .195 |
| 55 | .209 | .188 | .176 |
| 57 | .190 | .157 | .160 |
| 59 | .155 | .133 | .138 |
| 61 | .136 | .121 | .125 |
| 63 | .172 | .150 | .154 |

* Readings taken between gage positions 37 and 39.

吉野山 大正

REC'D - 10/10/78

1954年10月
 1954年10月

(year) - not identified
 (year) - not identified
 (year) - not identified
 (year) - not identified

[illegible]

0705

(2000000) - 10000000

22

35

[illegible]

12. The following information was obtained from the records of the Bureau of the Census:

TABLE X

Data Sheet

Date: 19 April 1954
 Test No.: 19 (continued)
 Plate No.: 1
 Strain Indicator
 Serial No. D58130
 Type K
 O.F. Setting 2.01

B-Edge Conditions

Load Application - Pump
 Jacks
 Bar - 3/4" (flat)(1)
 Gasket - Double Solder
 1/16" diam.

Segments
 Shims

| Load
Kips | Zero | 20 | | Zero | 20 |
|--------------|--------|------|------|--------|------|
| Gage | Strain | | Gage | Strain | |
| 7 | 6-851 | 1057 | 37 | 6-576 | 550 |
| 8 | 5-559 | 235 | 38 | 7-461 | 417 |
| 9 | 7-339 | 367 | 39 | 8-490 | 400 |
| 10 | 8-857 | 642 | 40 | 8-470 | 370 |
| 11 | 6-676 | 695 | 41 | 8-1028 | 961 |
| 12 | 6-1041 | 890 | 42 | 8-979 | 893 |
| 13 | 8-899 | 942 | 43 | 7-1288 | 1245 |
| 14 | 8-1293 | 1155 | 44 | 7-592 | 530 |
| 15 | 7-450 | 500 | 45 | 7-1204 | 1161 |
| 16 | 7-920 | 765 | 46 | 7-761 | 690 |
| 17 | 8-857 | 909 | 47 | 8-770 | 668 |
| 18 | 8-1269 | 1111 | 48 | 6-1089 | 990 |
| 19 | 6-1037 | 1030 | 49 | 7-433 | 305 |
| 20 | 7-733 | 563 | 50 | 6-1284 | 1200 |
| 21 | 8-1161 | 1130 | 51 | 7-558 | 475 |
| 22 | 7-582 | 466 | 52 | 4-860 | 802 |
| 23 | 7-1077 | 1024 | 53 | 6-404 | 341 |
| 24 | 8-450 | 371 | 54 | 7-388 | 350 |
| 25 | 8-943 | 833 | 55 | 7-836 | 712 |
| 26 | 8-381 | 301 | 56 | 7-1260 | 1209 |
| 27 | 6-862* | 760 | 57 | 8-986 | 820 |
| 28 | 7-943 | 892 | 58 | 6-428 | 396 |
| 29 | 6-1217 | 1097 | 59 | 7-1027 | 900 |
| 30 | 7-790 | 750 | 60 | 8-500 | 500 |
| 31 | 7-484 | 387 | 61 | --- | --- |
| 32 | 7-1140 | 1118 | 62 | --- | --- |
| 33 | 8-672 | 647 | 63 | --- | --- |
| 34 | 5-1002 | 859 | 64 | --- | --- |
| 35 | --- | --- | 65 | --- | --- |
| 36 | --- | --- | 66 | --- | --- |

* Doubtful reading.

(1) Ramp in lower bar over bottom jack and under gages 17 and 18.

TABLE 1

Data Sheet

3-Edge Condition

Remarks
Time

Load Application - Pump
Jacks
Bar - 3/4" (114") (1)
Contact - Double Bolster
1/16" diam.

Date: 19 April 1951
Test No.: 19 (continued)
Plate No.: 1
Strain Indicator
Serial No. D58130
Type
R
O.T. Setting 2.01

| Load
Kips | Time | Strain | Load
Kips | Time | Strain |
|--------------|-------|--------|--------------|-------|--------|
| 1 | 0-001 | 1024 | 1 | 0-001 | 1024 |
| 2 | 0-002 | 1025 | 2 | 0-002 | 1025 |
| 3 | 0-003 | 1026 | 3 | 0-003 | 1026 |
| 4 | 0-004 | 1027 | 4 | 0-004 | 1027 |
| 5 | 0-005 | 1028 | 5 | 0-005 | 1028 |
| 6 | 0-006 | 1029 | 6 | 0-006 | 1029 |
| 7 | 0-007 | 1030 | 7 | 0-007 | 1030 |
| 8 | 0-008 | 1031 | 8 | 0-008 | 1031 |
| 9 | 0-009 | 1032 | 9 | 0-009 | 1032 |
| 10 | 0-010 | 1033 | 10 | 0-010 | 1033 |
| 11 | 0-011 | 1034 | 11 | 0-011 | 1034 |
| 12 | 0-012 | 1035 | 12 | 0-012 | 1035 |
| 13 | 0-013 | 1036 | 13 | 0-013 | 1036 |
| 14 | 0-014 | 1037 | 14 | 0-014 | 1037 |
| 15 | 0-015 | 1038 | 15 | 0-015 | 1038 |
| 16 | 0-016 | 1039 | 16 | 0-016 | 1039 |
| 17 | 0-017 | 1040 | 17 | 0-017 | 1040 |
| 18 | 0-018 | 1041 | 18 | 0-018 | 1041 |
| 19 | 0-019 | 1042 | 19 | 0-019 | 1042 |
| 20 | 0-020 | 1043 | 20 | 0-020 | 1043 |
| 21 | 0-021 | 1044 | 21 | 0-021 | 1044 |
| 22 | 0-022 | 1045 | 22 | 0-022 | 1045 |
| 23 | 0-023 | 1046 | 23 | 0-023 | 1046 |
| 24 | 0-024 | 1047 | 24 | 0-024 | 1047 |
| 25 | 0-025 | 1048 | 25 | 0-025 | 1048 |
| 26 | 0-026 | 1049 | 26 | 0-026 | 1049 |
| 27 | 0-027 | 1050 | 27 | 0-027 | 1050 |
| 28 | 0-028 | 1051 | 28 | 0-028 | 1051 |
| 29 | 0-029 | 1052 | 29 | 0-029 | 1052 |
| 30 | 0-030 | 1053 | 30 | 0-030 | 1053 |
| 31 | 0-031 | 1054 | 31 | 0-031 | 1054 |
| 32 | 0-032 | 1055 | 32 | 0-032 | 1055 |
| 33 | 0-033 | 1056 | 33 | 0-033 | 1056 |
| 34 | 0-034 | 1057 | 34 | 0-034 | 1057 |
| 35 | 0-035 | 1058 | 35 | 0-035 | 1058 |
| 36 | 0-036 | 1059 | 36 | 0-036 | 1059 |

* Displaced reading.

(1) Pump in lower and upper position (see notes on page 100)

TABLE XI

Data Sheet

Date: 19 April 1954

B-Edge Conditions

Test No.: 19

Plate No.: 1

Strain Indicator

Serial No. D58130

Type K

G.F. Setting 2.01

Load Application - Pump

Jacks

Bar - 3/4" (flat)(1)

Gasket - Double Solder

1/16" diam.

Segments

Shims

| Gage | 3 | 4 | 67 | 68 |
|----------------|---|----------|---------|----------|
| Load
(kips) | Strain Indicator Reading (microinches/inch) | | | |
| Zero | 8-1384 | 4-500 | 7-1328 | 7-635 |
| 2 | 1360 | 505 | 1331 | 602 |
| 4 | 1364 | 484 | 1350 | 566 |
| 6 | 1368 | 463 | 1364 | 535 |
| 8 | 1370 | 443 | 1380 | 503 |
| 10 | 1373 | 421 | 1394 | 470 |
| 12 | 1378 | 398 | 1412 | 439 |
| 14 | 1382 | 374 | 1431 | 403 |
| 16 | 1390 | 346 | 1452 | 363 |
| 18 | 1401 | 317 | 1478 | 323 |
| 20 | 1417 | 280 | 1509 | 276 |
| 22 | 1438 | 239 | 1541 | 227 |
| 24 | 1468 | 182 | 1581 | 166 |
| 26 | 1510 | (120) | 1641 | (91) |
| | | (3-1120) | | (6-1091) |
| 28 | 1580 | 1032 | 1706 | 1005 |
| 30 | 1678 | 910 | 1810 | 883 |
| 32 | (1912) | 617 | (1940) | 670 |
| | (9-930) | | (8-980) | |
| 34 | 1220 | 318 | 1269 | 348 |
| 36 | 1995 | 2-320 | 1750 | 5-720 |

Maximum Load - 36.2 kips

(1) Keep in lower bar over bottom jack and under gages 17 and 18.

TABLE XII

Data Sheet

Date: 19 April 1954

B-Edge Conditions

Test No.: 20

Plate No.: 2

Strain Indicator

Serial No. D58130

Type K

G. F. Setting 2.01

Load Application - Pump
Jacks

Bar - 3/4" (Flat)

Gasket - Double Solder
1/16" diam.Segments
Shims

| Gage | 11 | 22 | 3 | 4* | 5 | 6 | 7 | 8 | 9 | 10 |
|------|---|------|------|------|-------|------|------|------|------|------|
| Load | Strain Indicator Reading (microinches/inch) | | | | | | | | | |
| Kips | 5- | 7- | 5- | 4- | 8- | 5- | 7- | 7- | 5- | 5- |
| Zero | 1202 | 848 | 1261 | 935 | 430 | 994 | 1017 | 564 | 911 | 1495 |
| 2 | 1182 | 841 | 1210 | 930 | 399 | 1010 | 988 | 574 | 882 | 1506 |
| 4 | 1165 | 845 | 1182 | 940 | 373 | 1024 | 955 | 586 | 844 | 1518 |
| 6 | 1143 | 847 | 1149 | 952 | 342 | 1044 | 920 | 602 | 828 | 1530 |
| 8 | 1122 | 850 | 1117 | 962 | 303 | 1064 | 880 | 622 | 801 | 1546 |
| 10 | 1093 | 854 | 1079 | 982 | 262 | 1097 | 830 | 648 | 767 | 1563 |
| 12 | 1067 | 867 | 1032 | 1011 | 211 | 1133 | 770 | 681 | 730 | 1588 |
| 14 | 1031 | 880 | 982 | 1057 | 152 | 1180 | 702 | 724 | 682 | 1619 |
| 16 | 994 | 902 | 919 | 1082 | 71090 | 1232 | 626 | 774 | 633 | 1649 |
| 18 | 947 | 927 | 850 | 1141 | 1003 | 1304 | 525 | 848 | 570 | 1702 |
| 20 | 888 | 963 | 753 | 1219 | 889 | 1402 | 400 | 936 | 494 | 1760 |
| 22 | 800 | 1020 | 600 | 1347 | 698 | 1566 | 6167 | 1110 | 357 | 1872 |
| 24 | 643 | 1126 | 4337 | 1117 | 6393 | 1799 | 6880 | 1302 | 211 | 1973 |
| 226 | 438 | 1294 | 4860 | 1770 | 6890 | 7212 | 5311 | 1720 | 4870 | 1249 |
| 28 | 41795 | 1763 | 000 | 1487 | 5800 | 1050 | 5390 | 1310 | 450 | 1540 |

Maximum Load - 29.5 Kips

* Erratic readings

TABLE III

Test Results

Test Conditions

Segment
BPM

Load Application - Pump
Leakage
Bar - 3/4" (1.125)
Gasket - Teflon
1.125 diam.

Date: 12 April 1964
Test No.: 20
Plate No.: 5
Strain Indicator
Serial No. D50130
Type K
O. F. Setting 2.01

| 0.00 | 1.00 | 2.00 | 3.00 | 4.00 | 5.00 | 6.00 | 7.00 | 8.00 | 9.00 | 10.00 | 11.00 | 12.00 | 13.00 | 14.00 | 15.00 | 16.00 | 17.00 | 18.00 | 19.00 | 20.00 | 21.00 | 22.00 | 23.00 | 24.00 | 25.00 | 26.00 | 27.00 | 28.00 | 29.00 | 30.00 |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 11.52 | 11.53 | 11.54 | 11.55 | 11.56 | 11.57 | 11.58 | 11.59 | 11.60 | 11.61 | 11.62 | 11.63 | 11.64 | 11.65 | 11.66 | 11.67 | 11.68 | 11.69 | 11.70 | 11.71 | 11.72 | 11.73 | 11.74 | 11.75 | 11.76 | 11.77 | 11.78 | 11.79 | 11.80 | 11.81 | 11.82 |
| 11.53 | 11.54 | 11.55 | 11.56 | 11.57 | 11.58 | 11.59 | 11.60 | 11.61 | 11.62 | 11.63 | 11.64 | 11.65 | 11.66 | 11.67 | 11.68 | 11.69 | 11.70 | 11.71 | 11.72 | 11.73 | 11.74 | 11.75 | 11.76 | 11.77 | 11.78 | 11.79 | 11.80 | 11.81 | 11.82 | 11.83 |
| 11.54 | 11.55 | 11.56 | 11.57 | 11.58 | 11.59 | 11.60 | 11.61 | 11.62 | 11.63 | 11.64 | 11.65 | 11.66 | 11.67 | 11.68 | 11.69 | 11.70 | 11.71 | 11.72 | 11.73 | 11.74 | 11.75 | 11.76 | 11.77 | 11.78 | 11.79 | 11.80 | 11.81 | 11.82 | 11.83 | 11.84 |
| 11.55 | 11.56 | 11.57 | 11.58 | 11.59 | 11.60 | 11.61 | 11.62 | 11.63 | 11.64 | 11.65 | 11.66 | 11.67 | 11.68 | 11.69 | 11.70 | 11.71 | 11.72 | 11.73 | 11.74 | 11.75 | 11.76 | 11.77 | 11.78 | 11.79 | 11.80 | 11.81 | 11.82 | 11.83 | 11.84 | 11.85 |
| 11.56 | 11.57 | 11.58 | 11.59 | 11.60 | 11.61 | 11.62 | 11.63 | 11.64 | 11.65 | 11.66 | 11.67 | 11.68 | 11.69 | 11.70 | 11.71 | 11.72 | 11.73 | 11.74 | 11.75 | 11.76 | 11.77 | 11.78 | 11.79 | 11.80 | 11.81 | 11.82 | 11.83 | 11.84 | 11.85 | 11.86 |
| 11.57 | 11.58 | 11.59 | 11.60 | 11.61 | 11.62 | 11.63 | 11.64 | 11.65 | 11.66 | 11.67 | 11.68 | 11.69 | 11.70 | 11.71 | 11.72 | 11.73 | 11.74 | 11.75 | 11.76 | 11.77 | 11.78 | 11.79 | 11.80 | 11.81 | 11.82 | 11.83 | 11.84 | 11.85 | 11.86 | 11.87 |
| 11.58 | 11.59 | 11.60 | 11.61 | 11.62 | 11.63 | 11.64 | 11.65 | 11.66 | 11.67 | 11.68 | 11.69 | 11.70 | 11.71 | 11.72 | 11.73 | 11.74 | 11.75 | 11.76 | 11.77 | 11.78 | 11.79 | 11.80 | 11.81 | 11.82 | 11.83 | 11.84 | 11.85 | 11.86 | 11.87 | 11.88 |
| 11.59 | 11.60 | 11.61 | 11.62 | 11.63 | 11.64 | 11.65 | 11.66 | 11.67 | 11.68 | 11.69 | 11.70 | 11.71 | 11.72 | 11.73 | 11.74 | 11.75 | 11.76 | 11.77 | 11.78 | 11.79 | 11.80 | 11.81 | 11.82 | 11.83 | 11.84 | 11.85 | 11.86 | 11.87 | 11.88 | 11.89 |
| 11.60 | 11.61 | 11.62 | 11.63 | 11.64 | 11.65 | 11.66 | 11.67 | 11.68 | 11.69 | 11.70 | 11.71 | 11.72 | 11.73 | 11.74 | 11.75 | 11.76 | 11.77 | 11.78 | 11.79 | 11.80 | 11.81 | 11.82 | 11.83 | 11.84 | 11.85 | 11.86 | 11.87 | 11.88 | 11.89 | 11.90 |
| 11.61 | 11.62 | 11.63 | 11.64 | 11.65 | 11.66 | 11.67 | 11.68 | 11.69 | 11.70 | 11.71 | 11.72 | 11.73 | 11.74 | 11.75 | 11.76 | 11.77 | 11.78 | 11.79 | 11.80 | 11.81 | 11.82 | 11.83 | 11.84 | 11.85 | 11.86 | 11.87 | 11.88 | 11.89 | 11.90 | 11.91 |
| 11.62 | 11.63 | 11.64 | 11.65 | 11.66 | 11.67 | 11.68 | 11.69 | 11.70 | 11.71 | 11.72 | 11.73 | 11.74 | 11.75 | 11.76 | 11.77 | 11.78 | 11.79 | 11.80 | 11.81 | 11.82 | 11.83 | 11.84 | 11.85 | 11.86 | 11.87 | 11.88 | 11.89 | 11.90 | 11.91 | 11.92 |
| 11.63 | 11.64 | 11.65 | 11.66 | 11.67 | 11.68 | 11.69 | 11.70 | 11.71 | 11.72 | 11.73 | 11.74 | 11.75 | 11.76 | 11.77 | 11.78 | 11.79 | 11.80 | 11.81 | 11.82 | 11.83 | 11.84 | 11.85 | 11.86 | 11.87 | 11.88 | 11.89 | 11.90 | 11.91 | 11.92 | 11.93 |
| 11.64 | 11.65 | 11.66 | 11.67 | 11.68 | 11.69 | 11.70 | 11.71 | 11.72 | 11.73 | 11.74 | 11.75 | 11.76 | 11.77 | 11.78 | 11.79 | 11.80 | 11.81 | 11.82 | 11.83 | 11.84 | 11.85 | 11.86 | 11.87 | 11.88 | 11.89 | 11.90 | 11.91 | 11.92 | 11.93 | 11.94 |
| 11.65 | 11.66 | 11.67 | 11.68 | 11.69 | 11.70 | 11.71 | 11.72 | 11.73 | 11.74 | 11.75 | 11.76 | 11.77 | 11.78 | 11.79 | 11.80 | 11.81 | 11.82 | 11.83 | 11.84 | 11.85 | 11.86 | 11.87 | 11.88 | 11.89 | 11.90 | 11.91 | 11.92 | 11.93 | 11.94 | 11.95 |
| 11.66 | 11.67 | 11.68 | 11.69 | 11.70 | 11.71 | 11.72 | 11.73 | 11.74 | 11.75 | 11.76 | 11.77 | 11.78 | 11.79 | 11.80 | 11.81 | 11.82 | 11.83 | 11.84 | 11.85 | 11.86 | 11.87 | 11.88 | 11.89 | 11.90 | 11.91 | 11.92 | 11.93 | 11.94 | 11.95 | 11.96 |
| 11.67 | 11.68 | 11.69 | 11.70 | 11.71 | 11.72 | 11.73 | 11.74 | 11.75 | 11.76 | 11.77 | 11.78 | 11.79 | 11.80 | 11.81 | 11.82 | 11.83 | 11.84 | 11.85 | 11.86 | 11.87 | 11.88 | 11.89 | 11.90 | 11.91 | 11.92 | 11.93 | 11.94 | 11.95 | 11.96 | 11.97 |
| 11.68 | 11.69 | 11.70 | 11.71 | 11.72 | 11.73 | 11.74 | 11.75 | 11.76 | 11.77 | 11.78 | 11.79 | 11.80 | 11.81 | 11.82 | 11.83 | 11.84 | 11.85 | 11.86 | 11.87 | 11.88 | 11.89 | 11.90 | 11.91 | 11.92 | 11.93 | 11.94 | 11.95 | 11.96 | 11.97 | 11.98 |
| 11.69 | 11.70 | 11.71 | 11.72 | 11.73 | 11.74 | 11.75 | 11.76 | 11.77 | 11.78 | 11.79 | 11.80 | 11.81 | 11.82 | 11.83 | 11.84 | 11.85 | 11.86 | 11.87 | 11.88 | 11.89 | 11.90 | 11.91 | 11.92 | 11.93 | 11.94 | 11.95 | 11.96 | 11.97 | 11.98 | 11.99 |
| 11.70 | 11.71 | 11.72 | 11.73 | 11.74 | 11.75 | 11.76 | 11.77 | 11.78 | 11.79 | 11.80 | 11.81 | 11.82 | 11.83 | 11.84 | 11.85 | 11.86 | 11.87 | 11.88 | 11.89 | 11.90 | 11.91 | 11.92 | 11.93 | 11.94 | 11.95 | 11.96 | 11.97 | 11.98 | 11.99 | 12.00 |

Maximum Load - 12.5 kpsi

* Strain readings

TABLE XIII

Data Sheet

Date: 19 April 1954
 Test No.: 20 (continued)
 Plate No.: 2
 Strain Indicator
 Serial No. D58130
 Type K
 G. F. Setting 2.01

B-Edge Conditions

Load Application - Pump
 Jacks
 Gasket - Double Solder
 1/16" diam.

Segments
Shims

| Gage | 1 | 3 | 5 | 7 | 9 |
|------|------------------------|------|-------|-------|------|
| Load | Deflection - d(inches) | | | | |
| Kips | | | | | |
| 1 | .218 | .276 | .296 | .265 | .289 |
| 10 | .205 | .288 | .302 | .294 | .314 |
| 15 | .225 | .322 | .371 | .317 | .342 |
| 20 | .257 | .373 | .429 | .404 | .384 |
| 24 | .309 | .468 | .522* | .522* | .457 |

* Limit of dial gage.

TABLE VIII

Table VIII

Handwritten notes and labels for Table VIII, including "Handwritten notes" and "Handwritten notes".

Handwritten notes and labels for Table VIII, including "Handwritten notes" and "Handwritten notes".

| Handwritten notes | Handwritten notes | Handwritten notes | Handwritten notes | Handwritten notes | Handwritten notes |
|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| Handwritten notes | Handwritten notes | Handwritten notes | Handwritten notes | Handwritten notes | Handwritten notes |
| Handwritten notes | Handwritten notes | Handwritten notes | Handwritten notes | Handwritten notes | Handwritten notes |
| Handwritten notes | Handwritten notes | Handwritten notes | Handwritten notes | Handwritten notes | Handwritten notes |
| Handwritten notes | Handwritten notes | Handwritten notes | Handwritten notes | Handwritten notes | Handwritten notes |
| Handwritten notes | Handwritten notes | Handwritten notes | Handwritten notes | Handwritten notes | Handwritten notes |

Handwritten notes and labels for Table VIII, including "Handwritten notes" and "Handwritten notes".

TABLE XIV

Data Sheet

Date: 21 April 1954

Test No.: 21

Plate No.: 3

Strain Indicator

Serial No. D58130

Type K

G.F. Setting 2.01

Load Application - Pump
JacksSegments
Shims

Bar - 3/4" (G)

Gasket - Single 3/32" solder

| Load
Kips | Gage No. | | Position from Vertical Centerline
(on Horizontal Centerline) | | | | | | | | |
|--------------|------------------------------------|-------|---|------|------|-----|-----|-----|-----|-----|-----|
| | 1 | 2 | -24" | -18" | -12" | -6" | 0 | 6" | 12" | 18" | 24" |
| | Strain Reading
(μ in./in.) | | Deflection (d")
(in. x 1000) | | | | | | | | |
| Zero | 8-542 | 8-769 | 65 | 86 | 85 | 82 | 64 | 60 | 40 | 30 | 05 |
| 2 | 534 | 762 | 57 | 89 | 83 | 73 | 50 | 43 | 26 | 17 | 03 |
| 4 | 521 | 760 | 55 | 84 | 76 | 67 | 42 | 33 | 15 | 9 | -05 |
| 6 | 507 | 760 | 55 | 82 | 75 | 65 | 36 | 12 | 14 | 9 | -02 |
| 8 | 489 | 761 | 55 | 81 | 76 | 66 | 37 | 30 | 12 | 8 | -- |
| 10 | 465 | 766 | 55 | 83 | 75 | 64 | 37 | 29 | 10 | 6 | -- |
| 12 | 437 | 771 | 55 | 82 | 74 | 61 | 34 | 24 | 8 | 4 | -- |
| 14 | 421 | 784 | 54 | 78 | 70 | 59 | 32 | 21 | 3 | 2 | -- |
| | | | x385 (Reset dial gage) | | | | | | | | |
| 16 | 398 | 794 | x384 | 405 | 396 | 384 | 357 | 343 | 325 | 324 | 317 |
| 18 | 365 | 810 | 383 | 403 | 391 | 356 | 350 | 337 | 320 | 320 | 314 |
| 20 | 327 | 831 | 382 | 400 | 383 | 372 | 342 | 328 | 311 | 313 | 310 |
| 22 | 271 | 868 | 380 | 394 | 378 | 360 | 330 | 316 | 300 | 306 | 307 |
| 24 | 200 | 921 | 376 | 387 | 366 | 346 | 314 | 299 | 287 | 295 | 302 |
| | 7-1200 | | | | | | | | | | |
| 26 | 1082 | 1018 | 368 | 370 | 346 | 322 | 289 | 275 | 267 | 281 | 295 |
| 28 | 874 | 1192 | 356 | 340 | 305 | 275 | 235 | 222 | 224 | 252 | 282 |
| 30 | 057 | 1871 | 299 | 227 | 166 | 133 | 106 | 112 | 129 | 180 | 252 |

Maximum Load - 32,500 pounds

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Handwritten notes:

- Load Application - Prop
- Time
- Temp - 37° (8)
- Height - 2' 30"

[illegible]

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TABLE XV

Data Sheet

Date: 21 April 1954

Test No.: 22

Plate No.: 4

Strain Indicator

Serial No. D58130

Type K

G.F. Setting 2.01

Load Application - Pump
Jacks

Bar - 3/4" (G)

Gasket - Single 3/32" diameter
solderSegments
Shims

| Load
Kips | Gage No. | | Position from Vertical Centerline
(on Horizontal Centerline) | | | | | | | | |
|--------------|------------------------------------|--------|---|------|------|-----|-----|-----|-----|-----|-----|
| | 1 | 2 | -24" | -18" | -12" | -6" | 01 | 6" | 12" | 18" | 24" |
| | Strain Reading
(μ in./in.) | | Deflection (d')
(in. x 1000) | | | | | | | | |
| Zero | 8-1307 | 7-1142 | 266 | 225 | 171 | 120 | 102 | 107 | 154 | 168 | 241 |
| 2 | 1281 | 1147 | 256 | 215 | 160 | 131 | 94 | 95 | 141 | 167 | 238 |
| 4 | 1259 | 1156 | 252 | 203 | 152 | 105 | 88 | 86 | 134 | 159 | 235 |
| 6 | 1225 | 1171 | 252 | 200 | 146 | 105 | 80 | 84 | 131 | 159 | 235 |
| 8 | 1193 | 1188 | 247 | 195 | 140 | 99 | 72 | 76 | 128 | 152 | 235 |
| 10 | 1157 | 1210 | 247 | 188 | 129 | 86 | 65 | 70 | 124 | 153 | 235 |
| 12 | 1111 | 1234 | 242 | 180 | 120 | 83 | 56 | 60 | 114 | 147 | 231 |
| 14 | 1059 | 1269 | 236 | 171 | 106 | 70 | 42 | 55 | 109 | 144 | 229 |
| 16 | 1000 | 1302 | 230 | 160 | 92 | 50 | 31 | 40 | 98 | 138 | 225 |
| 18 | 930 | 1361 | 226 | 148 | 73 | 27 | 18 | 30 | 90 | 131 | 222 |
| 20 | 851 | 1416 | 217 | 130 | 56 | 12 | 0 | 8 | 72 | 119 | 218 |
| 22 | 741 | 1510 | 206 | 111 | 10 | -- | -- | -- | 58 | 105 | 214 |
| 24 | 598 | 1615 | | | | | | | | | |
| 26 | 410 | 1772 | | | | | | | | | |
| 28 | 042 | 1965 | | | | | | | | | |
| 30 | 7-250 | 8-1640 | | | | | | | | | |

Maximum Load - 33,500 pounds

Date: 21 April 1954
 Test No.: 25
 Plate No.: 1
 Station: Johnston
 Serial No.: 258130
 Type: V
 O. Y. Section: 2.01

unlimited liability not collect
(unlimited liability not)

[illegible]

1990-1991

TABLE XVI

Initial Unfairness of Specimens

| Location from vertical
centerline (on horizontal
centerline) | Plate No. | | | |
|--|-----------|------|-------|------|
| | 1 | 2 | 3 | 4 |
| Initial deflection d_0 (in.) | | | | |
| -24" | --- | .055 | .004 | --- |
| -18" | --- | .036 | -.002 | .066 |
| -15" | --- | .043 | --- | --- |
| -12" | --- | .053 | -.007 | .074 |
| - 9" | .085* | .057 | --- | --- |
| - 6" | --- | .057 | -.009 | .057 |
| - 3" | --- | .051 | --- | --- |
| Centerline | --- | .041 | -.008 | .071 |
| + 6 | --- | .037 | .002 | .066 |
| +12 | --- | .031 | .000 | .033 |
| +18 | --- | .041 | .005 | .020 |
| +24 | --- | .054 | .006 | .021 |

* Maximum deflection under gage numbers 17 and 18, 8.04" from vertical centerline, 1.32 above horizontal centerline.

TABLE XVI

Initial Unitaries of Specimens

| I | Plate No. | | Initial Unitaries of Specimen (in %) | Location from vertical centerline (or horizontal centerline) (centimeters) |
|-----|-----------|------|--------------------------------------|--|
| | 1 | 2 | | |
| --- | 400. | 270. | --- | "-5" |
| --- | 300. | 280. | --- | "-10" |
| --- | --- | 240. | --- | "-12" |
| --- | 300. | 270. | --- | "-13" |
| --- | --- | 270. | 280. | "-2" |
| --- | 200. | 270. | --- | "-6" |
| --- | --- | 270. | --- | "-7" |
| --- | 200. | 240. | --- | Centerline |
| --- | 200. | 270. | --- | "+" |
| --- | 200. | 270. | --- | "12" |
| --- | 200. | 240. | --- | "18" |
| --- | 200. | 270. | --- | "20" |

* Maximum deflection under load was 1.5 mm. Initial unitaries were 1.5 mm above horizontal centerline.

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